RUSH VALLEY (STOCKTON) DISTRICT.

GEOGRAPHY.

The Rush Valley district is on the west side of the Oquirrh Range, about 40 miles southwest of Salt Lake City. The shipping points for the district are Stockton, on the Los Angeles & Salt Lake Railroad, and Bauer, a siding near the portal of the drain tunnel of the Bullion Coalition Co. All ore, excepting that taken through the Bullion Coalition tunnel, is hauled by teams 1 to 3 miles from the mines to the railroad.

The main mineralized area of the Rush Valley (Stockton) district is rather low down on the western slope of the Oquirrh Range, the outcrops of the main ore bodies being between 5,000 and 7,000 feet above sea level. In the higher parts of the range the topography is rugged, but in the lower slopes it is rather subdued. The earlier developments were mainly by winzes following the ore bodies, as the relief is not sufficient to make it possible to gain depth rapidly by tunnels. Several ore bodies have been developed by tunnels, however, above the water level and the large flows of water encountered as the workings were deepened made drain tunnels necessary. A large flow from the drain tunnel of the Bullion Coalition Co., the only deep tunnel of the district, is utilized for irrigation.

GEOLOGY.

SEDIMENTARY ROCKS.

The sedimentary rocks are interbedded limestones and quartzites. On the south, toward Soldiers Canyon, limestones predominate, but toward the north quartzites become increasingly abundant and appear to greatly predominate in the central and northern parts of the district. This appearance is due in part to the fact that the area is largely covered by débris and that the quartzite, being the more resistant, accumulates more rapidly than the limestone. Underground the quartzite is not conspicuous, but this is in part because prospecting has been largely confined to the limestone areas.

The quartzite is commonly fine grained and rather close jointed and readily breaks down into angular fragments. The limestone is blue or black and white. The blue beds are said to be nearly pure calcium carbonate and the white beds to be dolomitic and siliceous. The limestone of the Honerine mine is blue and lies between beds of white siliceous magnesian limestone, locally called "dolomite." With hydrochloric acid the blue limestone effervesces far more freely than the white. It has a specific gravity of 2.62 and the white of 2.88.

Partial chemical analyses by R. C. Wells of the blue limestone and the white limestone overlying it (see p. 174) show that the blue is nearly pure carbonate, whereas the white is very siliceous. The close similarity of the white bed underlying the blue limestone to that overlying it warrants the conclusion that the two are of essentially the same composition, and it is probable that a similar chemical difference exists between the blue and white limestones in other parts of the district.

IGNEOUS ROCKS.

There are numerous dikes in the district, but they are not conspicuous on the surface, as they weather more readily than the inclosing rocks and are obscured by débris. Many are encountered in the mine workings. In general they strike north, like the main fissures of the district. They range in thickness from a few inches to 60 feet or more.

The dikes vary considerably in general appearance, owing largely to their texture. Many are characterized by phenocrysts of orthoclase feldspar, some of which are an inch in greatest dimension.

In the coarser rocks there are many crystals of altered plagioclase and an abundance of biotite crystals. In some of the dikes augite can be seen in the hand specimen, though this mineral is commonly altered to other minerals.

The dikes are commonly too highly altered to make accurate determination of their original composition possible, but they all appear to have essentially the composition of a quartz monzonite.

STRUCTURE.

The largest structural feature of the district is a broad anticline that strikes west of north and pitches rather steeply north. The main mineralized area of the district is near the crest of this anticline, and consequently the beds strike generally east and dip 60° to 70° N., varying somewhat with their position relative to the axis of the anticline and to local structural features.

The sedimentary rocks in the district have been cut by a series of fissures that are about parallel with the anticline and are most strongly developed near its crest. They dip west usually at a rather steep angle, some reaching 70°. The different fissures vary somewhat in dip, as do also individual fissures at different points. Some movement has occurred along nearly all the fissures. In most of them it is not more than a few feet; in one, however, it is as much as 120 feet.

ORE DEPOSITS.

GEOLOGIC RELATIONS.

Practically all the larger ore bodies are found in beds, locally designated east-west "veins," of blue limestone, near the intersection of north-south fissures known as the north-south "veins." The ore occurs as shoots, pitching northwest, with the intersection of the ore bedding and fissures. Some replacements extend along the ore bedding for 100 feet, or even more, and some for only a few feet from the fissure. Individual shoots vary markedly from point to point. Some of them have been followed for 1,200 to 1,300 feet on the dip.

Experience has shown that mineralization is very likely to occur at the intersection of one of the ore beds with the fissures, and at present this is the guide to prospecting. Drifts are carried along the ore beds to the fissures or crosscuts are extended along the fissures to the ore beds, as is found most advantageous in individual cases. Many of these intersections show but little mineralization, but a large percentage of them show some.

Although for the most part the ore has formed in certain beds, some mineralization is present along the north-south fissures, both between the dolomitic or siliceous walls and between walls of the purer limestone. These deposits are commonly smaller than the limestone replacements, but some of them contain ore of relatively high grade.

No recognized close relation exists between the dike rocks and the ore deposits. Many dikes occupy the north-south fissures, and ore has formed adjacent to some of them.

Some of the more valuable ore bodies have formed on the footwall side of dikes, either immediately or several feet below. Mineralization has also occurred on the hanging-wall side, and it is not certain that the footwall is distinctly favorable. A similar condition has been noted in other districts, however, notably in the Fish Springs district, and may be of considerable importance. Although there does not appear to be any intimate relation between intrusive rocks and ore deposits, nevertheless the important ore deposits are not far from intrusive bodies and are absent from parts of the range where intrusive rocks are absent.

Faulting along fissures has displaced some beds from a few inches to as much as 120 feet. The main movement appears to have taken place before the ore deposition, though some of it was afterward. The fact that the faulting preceded the mineralization makes it no less important to find the separated portions of the ore bed, as both are likely to have been mineralized.

METAMORPHISM.

The typical change in the mineralized limestone is silicification and addition of sulphides. In many deposits the carbonates have been largely replaced by quartz and sulphides. Locally, fine-grained muscovite (sericite) is present, and specimens of limestone partly altered to epidote were collected from the dump of the drain tunnel of the Bullion Coalition mine. Contact silicates, however, are not abundant. The principal metallic sulphides in the ore shoots are galena, sphalerite, and pyrite, a little chalcopyrite and tetrahedrite, and in some specimens arsenopyrite, though this last does not appear to be an important constituent. The distribution of the sulphides in the unoxidized ore is irregular, some portions of a shoot being rich in galena, others in sphalerite or pyrite, and still others contain all three in considerable amounts. As yet comparatively little zinc ore of sufficient richness to make its marketing profitable has been developed, though some has been shipped and some mixed sulphide ore, both in the mines and on the dumps, may at some time be profitably treated.

The upper portion of the ore shoots has undergone oxidation, and the metals are commonly present as the carbonates, oxides, sulphates, and residual sulphides. The carbonate cerusite is the most abundant lead mineral in the oxidized zone. It is usually mixed with hydrated iron oxides but is occasionally found as small bodies of white, earthy car-

bonate resembling chalk. The sulphate anglesite is doubtless present to some extent, though not important. Plumbojarosite, the basic lead-iron sulphate, formed by the oxidation of lead and iron sulphides, was noted from the 600-foot tunnel level of the Bullion Coalition workings and from the Ben Harrison mine. It is not possible to state how abundant it is as an ore mineral, as it has not generally been recognized. Zinc is present in the oxidized ore as the carbonate smithsonite, but no bodies of oxidized zinc comparable with those in the sulphide zone have been developed. In Dry Canyon, to the south, zinc occurs in considerable amount in the oxidized zone. In numerous lead mines in the West oxidized zinc has been overlooked or neglected and has later been revealed in payable bodies upon the examination of old workings, and it is possible that such would be found in this district, though the writer knows of no reason except the presence of considerable zinc in the sulphide zone for so believing. The iron sulphide has commonly altered to hydrous iron oxide and to the basic sulphate.

TENOR OF THE ORES.

The ores of the district as a whole are of relatively low grade, and concentration has been necessary to raise much of the ore to a shipping grade.

According to the census report for 1880 the first-class ores from the Great Basin mine, the most important producer at that time, averaged 40 per cent lead, from 18 to 21 ounces silver, and $2 gold per ton.[1] Concentrating ores are estimated to have averaged 8 ounces silver per ton and 13 per cent lead.

The ore in the sulphide zone, like that in most of the lead-silver deposits of the State, is of lower grade than the oxidized ore and seems likely to prove less profitable.

MINES.

The principal mines operating in the district in 1912 were the Bullion Coalition, including what was formerly known as the Honerine and at an earlier period as the Great Basin; the New Stockton, formerly known as the Ben Harrison, and the Galena King. Other prospects shipped some ore in the same year.

[1] Tenth Census U. S., vol. 13, p. 447, 1885.

The Honerine mine was located in 1865 by Gen. Conner and in early days made a large production, estimated at about $1,250,000. The largest ore shoot, which occurred at the intersection of the "Honerine vein" or bed of blue limestone and a prominent north-south fissure, has been followed practically continuously, though pinching and swelling, for 1,200 to 1,300 feet down the dip. Valuable ore shoots have been developed in other beds of limestone at the intersection of north-south fissures, including those locally known as the St. Patrick, Hercules, and Ada.

The mine was first developed by a winze. Later a tunnel was driven that cut the main ore shoot about 600 feet below the outcrop. When the cost of pumping became excessive, a drain tunnel was driven from a point just above the level of Rush Valley. In 1912 this had been extended about 1,200 feet and intersected the ore bodies about 600 feet below the upper or 600-foot tunnel. Later, pumps were installed and a winze sunk below the tunnel level. Near the portal a concentrating mill, which utilizes the large flow of water from the tunnel, has been operated intermittently in recent years. The mine has been operated in part by the company and in part by lessees. Some of the ore was hand sorted by lessees, and second-class ore was concentrated in jigs to a profitable grade.

The Galena King mine is in the gulch above the Honerine mine. The geologic relations are in general similar, though the sedimentary beds stand at a somewhat steeper angle. The ore forms shoots near the intersection of certain limestone beds with north-south fissures. Oxidation has been rather complete to a depth of about 800 feet. Between 800 and 1,000 feet sulphides predominate, though there has been considerable oxidation. Some of the shoots carry considerable zinc in the lower levels, though it is not reported that zinc was abundant in the upper levels. The original water level was at about the 800-foot depth, but the mine is now drained by the Honerine tunnel to the lowest workings. The mine is developed to the 1,000-foot level by an inclined shaft.

The Ben Harrison mine, of the New Stockton Co., is in the northeastern part of the district.

The sedimentary rocks are at a higher horizon than those farther south, and quartzitic sand-

stones predominate with interbedded limestone. The dip of the beds is also steeper, being nearly perpendicular or locally dipping to the south. Dikes of porphyritic rock, similar in character to the other dikes of the district, are present. The sedimentary series here, as farther south, is cut by north-south fissures that dip rather steeply west.

Ore occurs as a replacement of the limestone near the intersections of the north-south fissures. The mineralization is similar in character to that farther to the south, but the deposits contain more manganese. Oxidation has been rather complete to a depth of about 800 feet below which the ore is mainly sulphide, though some oxidation extends to the 1,000-foot level.

The mine is opened by a 1,000-foot vertical shaft. It is equipped with a mill of a capacity of about 50 tons a day. In 1912 the mine was being worked by lessees. The second-class ore was jigged to bring it to shipping grade.

In a property northeast of the Ben Harrison mine the ore, unlike most of that from the district, is confined largely to the north-south fissures in quartzite. The ore is in part galena and in part oxidized and runs unusually high in silver for this district. Some of it is siliceous and owes its value mainly to silver. The ore bodies are small as compared with those forming as a replacement of the limestone beds.

Other properties in the district have made production in the past and some of them doubtless will contribute to the future output of the district.

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OPHIR DISTRICT.

GENERAL FEATURES.

The Ophir district is on the west side of the Oquirrh Range, about 8 miles south of the Rush Valley district. It extends from Soldiers Canyon on the north to the Camp Floyd or Mercur district on the south. It has three divisions—Dry Canyon, in the north, Ophir Canyon in the center, and Lion Hill in the south. Previous to 1912 the ores from the Ophir and Lion Hill districts were freighted to St. Johns and those from Dry Canyon to Stockton. In 1912 a standard-gage railroad was completed from St. Johns to Ophir.

The district is one of strong relief. The crest of the range is about 10,500 feet and the plain at its western base about 4,500 feet above sea level. The western slope is cut into a series of ridges separated by deep canyons, of which Soldiers, Dry, and Ophir canyons are the most important.

GEOLOGY.

The rocks of the district are largely sedimentary, though there are dikes and sills of intrusive rocks.

SEDIMENTARY ROCKS.

The sedimentary rocks consist of quartzites, shales, and limestones ranging in age from Cambrian to Carboniferous. The lowest formation exposed is a medium-grained reddish Cambrian quartzite on the north side of Ophir Canyon. Its thickness is not known, though several hundred feet of its upper portion is exposed.

Overlying the quartzite is a series of shales with interbedded limestone, to which the name Ophir formation is herein given. (See p. 79.) These rocks show some metamorphism, the shales especially having developed a schistose character. Certain beds of the limestone are commonly composed of light-gray and dark-gray bands, most of them only a fraction of an inch thick. Both the light and dark effervesce with diluted hydrochloric acid, but the light are apparently the purer. In many places, where partly replaced by ore or other minerals, the banding is preserved. This series has a thickness of upward of 100 feet. Fossils collected from it were reported by L. D. Burling to be of Lower Cambrian age and the rocks to be probably correlated with the Pioche shale. Overlying the shales, apparently conformably, a great thickness of rather heavy bedded limestones, mostly bluish, with some lighter colored and a few shaly beds, extends into Dry Canyon. North of Dry Canyon considerable quartzite is interbedded with the limestone. A poorly preserved trilobite collected several hundred feet above the shale series was reported by Mr. Burling as probably

Cambrian. Gansl and Keep [1] report 1,200 feet of Cambrian limestone.

The lowest horizon from which Carboniferous fossils (determined by G. H. Girty to be lower Mississippian) were collected is 200 to 300 feet below the ore bed of the Cliff mine; and several collections made between this level and the summit of the divide between Ophir and Dry canyons proved to be of the same age. Collections from the north side of Dry Canyon and from midway between Dry and Soldiers canyons proved to be upper Mississippian, and fossils from just north of Soldiers Canyon were determined as Pennsylvanian.

Specimens of dark shaly rock collected from the dump of the Hidden Treasure mine in 1912 proved on examination in the Survey laboratory to be phosphatic. Since that time considerable phosphatic rock has been reported from this horizon.

In Lion Hill, south of Ophir Canyon the same series of rocks is exposed as to the north, though the section is not so complete. Neither the Cambrian quartzite nor shale series is exposed south of the canyon, and the rocks have been eroded from the surface down to the lower Carboniferous.

Sufficient fossils have not been collected to show how much of the great series of limestones belongs to the periods between Cambrian and Carboniferous. No fossils of Devonian, Silurian, or Ordovician age were collected, and no sediments may have been deposited during those periods, though this does not seem probable, as both Ordovician and Devonian are present in the neighboring Tintic district. Unconformities are present in the Tintic district below the Carboniferous and Ordovician, and it is possible that the Devonian and Ordovician and the upper part of the Cambrian were removed by erosion. It seems probable that the lower 1,200 feet of the formation is pre-Carboniferous and may include some post-Cambrian strata.

IGNEOUS ROCKS.

Igneous rocks have relatively slight areal distribution in the district. The largest bodies are around Lion Hill, where they have been mapped by Emmons and Spurr. In his report on the Mercur district to the south Spurr [2] has described two types of porphyry which he has called the Eagle Hill and Birdseye porphyries. The "Birdseye" is composed of abundant phenocrysts of feldspar with rather pleutiful biotite and a few phenocrysts of quartz in a fine-grained groundmass. The rock is commonly highly altered and its original composition can not be positively determined, though it is probably that of a quartz monzonite. The Eagle Hill porphyry is a fine-grained rock containing few inconspicuous phenocrysts of feldspar, biotite, and quartz. The freshest rock is light gray to nearly white but in places alters to yellow or pinkish. It also is too highly altered to permit determination of its original composition, though it appears to have been more acidic than the "Birdseye" porphyry.

The "Birdseye" porphyry outcrops at numerous points around Lion Hill and has been encountered in the underground workings. Apparently it forms a sheet between the limestone strata. It is also present on Porphyry Hill and Porphyry Knob southwest of Lion Hill.

The Eagle Hill porphyry is shown on a reconnaissance map by Emmons and Spurr [3] as a sheet near the summit of Lion Hill, but the rock is difficult to recognize in its highly altered condition, and a detailed study of the area is necessary to determine its extent and position.

North of Ophir Canyon dikes cut the limestones. One striking generally north outcrops east of the Cliff mine and can be followed with some interruptions for more than a mile. Near the divide between Ophir and Dry canyons its outcrop forms a conspicuous white cliff. The rock is fine grained and resembles the Eagle Hill porphyry.

Several dikes are present in Dry Canyon, all of those noted striking generally north. Some of them contain abundant porphyritic crystals and resemble the "Birdseye" porphyry more strongly than the Eagle Hill porphyry.

Spurr considers that the two types of porphyry of the Mercur district were derived from a common magma, and it seems probable that the same holds true for the porphyries in the Ophir district.

[1] Gansl, J. C., and Keep, G. A., The Ophir mining district of Utah: Salt Lake Min. Rev., vol. 12, p. 17, 1910.

[2] Spurr, J. E., Economic geology of the Mercur mining district: U. S. Geol. Survey Sixteenth Ann. Rept., pp. 377-381, 1895.

[3] Op. cit., pl. 25, p. 360.

STRUCTURE.

Folds.—Folding is the most prominent structural feature in the Ophir district and is beautifully shown on the steep slopes of Ophir Canyon. Emmons and Spurr [1] have shown that the southern end of the Oquirrh Range consists of a broad anticline on the west and a corresponding syncline on the east, both striking generally northwest. The crest of the anticline passes about through the summit of Lion Hill, through the main workings of the Ophir Hill mine, a little west of the principal mines in Dry Canyon, and through the workings of the Queen of the Hill mine on the north side of Dry Canyon.

From Ophir the rocks of the western anticline dip away in all directions in a pronounced dome or quaquaversal structure. The dips to the north are rather pronounced, being as much as 25° to 30° just north of Ophir and becoming steeper farther north. South of Ophir Canyon the dips are much less.

Faults.—In determining the principal large features of this part of the range faulting has been much less important than folding. Some faults, however, are important structurally and some of less magnitude are important economically.

The important Ophir Canyon fault strikes north of east, nearly parallel with Ophir Canyon, and dips steeply south. The vertical force that domed the strata apparently caused them to break along the line of this fault and raised the portion to the north more than that to the south, bringing the Cambrian quartzites against the lower part of the great limestone series. The displacement was greatest at the center of the dome and decreased both to the east and west. To determine the throw of the fault will require detailed geologic work to correlate the corresponding horizons in the limestones on opposite sides of Ophir Canyon. It is evident, however, that the throw is at least equivalent to the thickness of the Cambrian quartzites and shales exposed to the north of the fault, which amounts to several hundred feet.

Faults parallel to the main Ophir Canyon fault with throws of 40 feet or less have been encountered in the workings of the Ophir Hill mine, and other minor faults are present toward the Dry Canyon divide. In the Dry Canyon area detailed mapping will be required to determine the position and throw of the rather complex faults. Some of the important ore bodies of this district are reported to have been cut off by faults.

Fissures.—The limestone has been broken by fissures that trend generally north. They show little displacement and are important chiefly as channels for the ore-bearing solutions. They can not be recognized or traced on the surface, and their distribution is known only so far as they have been encountered in mine workings. From this, however, they appear to be most abundant near the crest of the anticline and to decrease in importance as the distance from the crest increases. This is of course the condition that would be normal if they have resulted from the bending of the limestone beds, for the crest of the anticline would be subjected to the greatest strain.

[1] Spurr, J. E., op. cit., pl. 25, p. 360.

ORE DEPOSITS.

The ore deposits of the district show a general similarity in mode of occurrence but differ greatly in metal contents. The Dry Canyon and Ophir Canyon ores carry lead-silver and some zinc and copper; and the ores from Lion Hill carry typically silver, commonly some gold and lead, but very little copper and zinc.

REPLACEMENT DEPOSITS.

Practically all the deposits of the district have formed as replacements of certain beds of limestone in typical shoots or pipes following the intersections of the replaced beds and the ore-bearing fissures. In detail, however, they differ considerably. In some replacement has extended for a considerable distance from the fissures and has formed tabular bodies of ore; in others it has formed relatively small pipes. The position of the ore shoot is largely controlled by the position of the replaced limestone bed and the ore fissure. Most of the fissures are very steep, and many of them are nearly vertical, but the dip of the limestone beds varies greatly, and this dip governs the pitch of the ore shoots.

ALTERATION OF THE LIMESTONE.

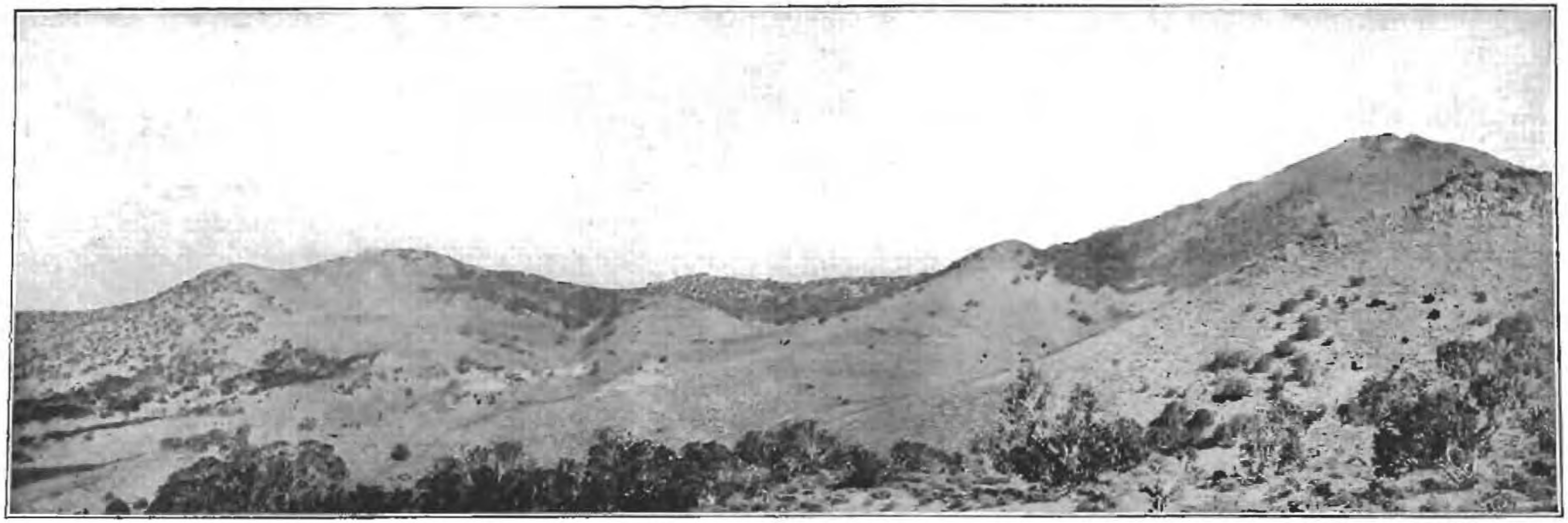
In some places the alteration of the limestone by the ore-bearing solutions consists mainly of a replacement of the rock by the sulphide minerals forming the primary ore. In

A. SPECIMEN OF ROCK FROM THE OPHIR HILL MINE, SHOWING ALTERATION OF LIMESTONE THAT CONTAINS ORE DEPOSITS.

Layers containing crystals of pyrite are composed largely of epidote with orthoclase and quartz; intervening bands composed largely of quartz and orthoclase. Two-thirds natural size.

B. PHOTOMICROGRAPH SHOWING GRADATION FROM EPIDOTE LAYER TO QUARTZ-ORTHOCLASE LAYER.

Lower right area, mainly epidote; central band, mainly quartz and grains of pyrite; upper left area, quartz and orthoclase with some epidote. Enlarged 30 diameters.



A. VIEW OF WEST TINTIC DISTRICT IN THE VICINITY OF SCOTIA MINE, SHOWING CHARACTERISTIC EXPOSURE OF GEOLOGIC FORMATIONS.

B. LION HILL, SHOWING OPHIR ANTICLINE ON SOUTH SIDE OF OPHIR CANYON, OPHIR.

Photograph by George St. Clair.

other places the character of the limestone adjacent to the ore has been entirely changed.

In the Dry Canyon area the limestone shows relatively slight alteration. It has undergone some though usually not pronounced silicification and contains some silicate minerals. Veinlike masses of tremolite and wollastonite in limestone found on the dump of the Hidden Treasure mine have apparently resulted from replacement along fissures. In the silicified rock nearly perfect quartz crystals in carbonate grains and rather abundant negative rhombohedral crystals filled with liquid and gas are present, indicating that the carbonate has also been recrystallized. The gas bubbles in these cavities do not ordinarily occupy more than 20 per cent of the space. Near the Cliff mine garnet intergrown with sulphides was collected at several points. Epidote was noted in a similar relation, and it is evident that these silicates have resulted from the action o the ore solutions on the limestone.

The limestone beds adjacent to the ore bodies of the Ophir Hill mine have suffered very great changes. Least altered is a light-gray limestone having a rather striking and characteristic banding of light and dark gray layers, both of which effervesce freely with dilute hydrochloric acid. No chemical analysis of the rocks has been made, but the lighter-colored bands from qualitative tests appear to consist of nearly pure calcium carbonate and the darker beds to contain more impurity, mainly in the fo m of silica. In the ore deposits this limestone has been largely replaced by ore sulphides and by gangue minerals and this grades along the bedding into rock that has been converted very largely into silicates and quartz and some sulphides. Th banding has commonly been preserved in this alteration (see Pl. XXXVII), except that instead of forming continuously in the bands the secondary minerals have in many places formed in lens-shaped bodies along a particular band.

In this altered rock epidote is abundant in green bands or lenses, surrounded by a light band about an eighth of an inch thick and the remainder consists of a gray mass, resembling unaltered limestone but harder. In thin section the green areas are seen to consist largely of epidote with minor amounts of orthoclase and a few crystals of wollastonite. The light area surrounding the epidote is composed largely of orthoclase and some epidote; and the gray mass consists of orthoclase, minute crystals of epidote, quartz, and sericite, which in places is rather plentiful. The minerals in these gray areas are very fine grained and difficult of determination, and it is possible that still others are present. It is evident, however, that the more important minerals resulting from the alteration are epidote, orthoclase, sericite, and quartz.

A partial analysis of the material of the gray areas and the light bands by W. C. Wheeler, of the United States Geological Survey, gave K_2O 9.50 per cent, Na_2O 0.83 per cent. If the alkalies are all calculated as feldspars it gives 63 per cent as the feldspar content of the rock.

It may be mentioned that locally, especially along the contact of quartzite and limestone, sericite (muscovite) is present in relative purity as a white micaceous substance commonly called "talc."

The typical alteration of the limestone at Lion Hill is silicification, the altered limestone or "zone rock" being very largely replaced by quartz. Considerable sericite is, however, scattered through the rock and in places is rather abundant; barite is also rather plentiful but typically is a vein rather than a replacement mineral.

The alteration in the area is confined to a rather definite stratum ranging from a few feet to several scores of feet in thickness that normally and possibly invariably lies directly or closely beneath a sheet of porphyry. It is in this area of altered rock that most of the ore bodies have been found and for this reason it is commonly designated in the district as the "zone rock."

DRY CANYON.

In the early days of mining Dry Canyon yielded large amounts of ore, some of it of high grade. At the time of visit, in 1912, there was comparatively little activity. Lessees were taking ore from the Hidden Treasure property both from underground and from the old dumps, and some ore was being taken from other properties. Since 1912 considerable zinc from oxidized ores and other metals has been produced.

As in many of the older districts, the inaccessibility of many of the workings makes study of the ore deposits rather unsatisfactory.

Moreover, there has been considerable faulting that can be worked out satisfactorily only by detailed mapping. The following notes on the mines are derived in part from early descriptions and in part from the writer's observations. For several mines no data are available. The oxidized zinc and copper ores have been described by Loughlin.[1]

Hidden Treasure mine.—The Hidden Treasure mine was the first to be located in the Dry Canyon and has been one of the largest producers. The limestone beds strike about N. 70° E. and dip about 30° NW. These beds are cut by fissures striking N. 35° to 40° W. and by several porphyry dikes, which, however, appear not to be intimately associated with the ore.

The ore deposits have formed as a replacement of the limestone adjacent to the fissures. The workings have been described as follows:[2]

The ore is found in one or two chimneys in a bedded vein in a compact bluish limestone, which dips about 30° N. 32° W. About 3 feet above the ore there is a contact vein an inch or so in width between an overlying stratum of siliceous slate (locally called "block slate") and the limestone beneath. Very rarely, however, does the ore body make to the contact (in some of the upper works the ore was on the contact). One chimney began at the surface, or at least within 60 feet of it, and continued for 600 feet. It then split into two chimneys, which continued 800 feet or more. The upper chimney was from 20 to 100 feet wide and from 3 to 20 feet thick. The branches were from 10 to 25 feet wide and from 1 inch to 20 feet thick. The ore found in the Chicago mine was in two bedded pipes, which were in a limestone stratum about 100 feet beneath these ore bodies. The pipes turned upward and finally connected with the Hidden Treasure vein. The ore of the Hidden Treasure is a soft reddish-brown ocher containing cerusite, galena, and traces of copper carbonates. It assays from 15 to 40 ounces silver and 20 to 50 per cent lead. A few hundred feet to the north of this mine, in the direction in which the ore bodies dip, a great dike of granitic porphyry cuts through the country. The mine was formerly opened by five inclines, three of which were in ore, and several tunnels. It was worked at the period under review through a 500-foot tunnel, from which an 800-foot incline was sunk between the two chutes of ore. The extent of the workings on this stratum was 1,600 feet on the dip and 450 feet horizontally.

Since the above description was written, a lower tunnel has been driven and connected with the old workings.

The production in the early days was from the lead-silver "carbonate" ores. Zinc blende is mentioned as occurring in the mine, but at that time zinc ores were of no value. In 1912 the principal production was in the zinc carbonate ore that was being taken from old stopes from which lead ore had been extracted. Apparently the zinc ore was nearly free from lead, and according to descriptions much of the lead ore mined was comparatively free from zinc, suggesting a separation of the two metals during oxidation. In places, however, the oxidized zinc ore could be traced into sulphide ore, which was quite as free from lead as the zinc ore, a fact which strongly suggests separation of the sulphides. Both the sulphide and carbonate zinc ores were relatively low in silver. That zinc ore was rather abundant in the mine is shown by the amount thrown on the dump as waste in the extraction of the lead ores. In 1912 the dumps were being sorted principally for their zinc.

Copper is present but not in large quantity. It is generally in the form of the carbonates, malachite and azurite, though the copper-iron-lead sulphate beaverite and the double copper-zinc carbonate aurichalcite were collected from the mine dump. Some specimens of the zinc ore that were not stained with iron are slate-blue in color and on testing show the presence of considerable copper. It is probable that this bluish zinc carbonate contains variable amounts of copper and that it is not of definite composition. Specimens collected from the dump show the replacement of sphalerite, chalcopyrite, and galena by covellite, but no opportunity was afforded for determining the amount of this secondary sulphide ore.

Chicago mine.—The Chicago mine is described as follows:[3]

The Chicago mine was located in 1871, and sold to an English company soon afterwards. The mine was worked vigorously for several years but has been idle since 1876. Ore was found in two pipes 60 feet apart in the "reef" of limestone under the Hidden Treasure. These pipes came to within a few feet of the surface, covered only by the iron cap, and diverged somewhat as they went down. They were in general about 2½ feet in diameter but varied in shape considerably, especially beyond 400 feet. One pipe was followed 1,300 feet, and decreased in size until it was only 6 inches in diameter, when work was abandoned. This had five smaller pipes branching from it. The second pipe went down quite regularly for 800 feet, then suddenly rose 60 feet and continued on its

[1] Loughlin, G. F., Zinc carbonate and related copper carbonate ores at Ophir, Utah: U. S. Geol. Survey Bull. 690, pp. 1-14, 1918 (Bull. 690-A).
[2] Tenth Census U. S., vol. 13, p. 452, 1885.
[3] Tenth Census U. S., vol. 13, p. 452, 1885.

course. A second rise brought it to the Hidden Treasure vein. The ore is ocherous, assaying from 25 to 35 ounces silver and from 40 to 45 per cent lead. On the sides of the pipe there is usually from 6 inches to a foot of a valueless oxide of iron, frequently stained by copper carbonates. The total cuttings amount to about 5,000 feet. The mine produced considerably over 12,000 tons of ore.

Mono mine.—The Mono mine has been one of the large producers of the district. The exact metal output is not known but has been estimated at about $1,000,000. The main production was made in early days, when a shoot of very rich ore was followed till (as reported) it was cut off by a fault. For part of its extent at least the ore shoot underlies a rather thick bed of black shale which in many places has been crushed to an impervious gouge that appears to have stopped the ore solutions and caused them to replace the limestone underneath. The early workings were described as follows:[1]

Ore began at the surface and was found in a chute from 10 to 50 feet long, from 3 to 5 feet wide, and 300 feet deep. Below that depth it was in a series of small deposits. It was an oxidized ore, from silver, lead, copper, and iron sulphides. Slabs of horn silver were frequently found so soft that they would retain the impression of a coin, like wax. Its value, by the ton, was from $150 to $5,000 in silver. This ore occurs in a stratum of clay shale. The ore chute seems to cross this stratum and enter a black shale at a depth of 400 feet. In the lower workings the ore was limited in quantity and only assayed about $100 per ton.

The Mono tunnel is in the gulch about 800 feet below the upper workings and is designed to develop the area at greater depth. Some ore has been found in this tunnel, but as yet no bodies comparable in amount and value to those in the upper workings have been found.

Queen of the Hills mine.—The Queen of the Hills mine, including the Queen of the Hills, Flavilla, and Mahogany locations, was not in operation at the time of visit. These claims have been described as follows:[1]

These claims are on three chimneys in a bedded vein from 1 to 6 feet wide, dipping 17° to 25° W. between a siliceous limestone above and a blue limestone stratum below. * * * The dip of the chimneys is N. 30° W., being oblique to the dip of the strata. * * * The first chimney was 350 feet long (before being cut by the fault) and was from 25 to 40 feet wide, having a thickness of from 18 inches to 2 feet of ocherous ore containing but little copper and said to assay from 20 to 25 ounces silver and 50 per cent lead. The second chimney was 1,000 feet long, from 60 to 70 feet wide, and also had from 18 inches to 2 feet of ore, generally upon the hanging wall, assaying about 40 ounces silver and 30 per cent lead. The third chimney was about the same size as the second, but the ore contained some tetrahedrite, much malachite, and little lead, and assayed about 60 ounces silver. Recently zinc ore has been shipped from this mine.

[1] Tenth Census U. S., vol. 13, p. 453, 1885.

Kearsarge mine.—The Kearsarge mine has been described as follows:[1]

The ore-bearing formation is a stratum of limestone, in which the ore occurs in chimneys and exceedingly irregular masses. The overlying stratum or hanging wall is a very compact siliceous limestone. One chimney began at the surface and went down 500 feet. * * * The ore is a soft ocher, similar to that of the Hidden Treasure but much richer. The mine was opened by a 945-foot incline, having a dip of 30° to 35°. The ore continued in the bottom of the incline 20 inches in width, but water had stopped the work.

Other mines.—Other mines that made considerable production in early days were the Deseret group, Utah Queen, Sacramento, Mountain Savage, Emporia, Fourth of July, and Wandering Jew.

OPHIR CANYON.

Cliff mine.—The Cliff mine is on the north slope of Ophir Canyon, a few hundred feet below the Dry Canyon divide. The mine was worked in the early days and since 1905 has been one of the important producers of the district.

The sedimentary rocks are limestones of lower Carboniferous age, probably near the base of the Carboniferous, for fossils of this age were found only a few hundred feet below the ore horizon. The main development is a little to the east of the crest of the anticline, where the sedimentary beds dip about 30° a little east of north. A prominent porphyry dike striking about north and dipping steeply east cuts the sedimentary series a short distance west of the main workings. The sedimentary rocks are also cut by fissures striking a little east of north and dipping steeply east.

Ore bodies have been developed as very irregular replacements of the limestone along four fissures at two main horizons 40 to 50 feet apart. They pitch northeast in common with the intersection of the bedding and fissures. The limestone associated with the ore has been silicified and garnetized to some extent. The contact of the limestone and porphyry dike has been prospected for a short distance.

Some mineralized rock is present but no ore has been found.

The principal primary sulphide minerals are galena, pyrite, sphalerite, and chalcopyrite. Adjacent to the fissures these have been largely altered to secondary minerals, principally carbonates and oxides and minor amounts of other minerals, including the lead-iron sulphate plumbojarosite. Near the fissures oxidation has usually been rather complete, but farther from the fissures, away from the main channels of circulation, sulphides are more plentiful and some nearly pure sulphide ore has been mined.

The most important output has been lead and silver, but the mine has also produced considerable copper and some zinc. The ores have been only moderately rich, but those thus far extracted have been of a shipping grade. The mine has been opened by three tunnels at successively lower depths, and in 1912 an incline had been sunk to a depth of 550 feet on the dip below the lower tunnel. The ore is transported to the railroad in Ophir Canyon by an aerial tram. Previous to 1912 it was freighted by traction engine from the base of the tram to St. Johns.

Ophir Hill mine.—The Ophir Hill mine of the Ophir Hill Consolidated Mining Co. is on the north side of Ophir Canyon, about half a mile northwest of Ophir. The ore bodies occur in the Cambrian shale-limestone series (Ophir formation) overlying the Cambrian quartzite. In the mining developments five strata of limestone have been recognized, though they are not entirely distinct at all points. The shale, especially in the lower part of the series, has been metamorphosed to a distinctly schistose rock. The limestone beds have suffered comparatively little alteration except that caused by the ore solutions. Several of the beds are composed of light and dark gray layers which give the rock a characteristic banded structure. Overlying the limestone-shale series are heavy-bedded blue limestones, in which little ore has been developed.

The developed area is just north of the Ophir Canyon fault and near the crest of the dome. The beds strike generally east and dip about 25° a little east of north. Several minor faults that appear in the mine strike generally east. In most of them the downthrow is to the north, but in the most northerly it is to the south. Most of the throws are only a few feet, though that of the "Big" fault is about 40 feet.

A series of fissures striking a little east of north cut the sedimentary rocks nearly at right angles to the bedding and about parallel to the anticline and dip steeply west. They show no extensive movement, and as they cross the east-west faults with little or no displacement, they appear to be the youngest structural features. Four systems of replacement deposits—the Wild Delirium, Miners Delight, West stope, and Clark stope—have been developed adjacent to these fissures in each of five limestone beds or "veins."

The thickness of the ore beds changes somewhat from place to place but is approximately as follows: Top vein, 5 feet; Big vein, 20 feet; Middle vein, 10 feet; Copper vein, 8 feet; Blue vein, 6 feet. These "veins" are not everywhere entirely distinct, and at some points the Top and Big veins and the Blue and Copper veins are mined together. The maximum distance from the fissures to which the limestone has been replaced by ore minerals is 40 feet, and possibly more. The most extensive deposits are associated with the east-west faults, the limestone adjacent to which appears to have been crushed and thus rendered more permeable and susceptible to replacement. The primary ore minerals are pyrite and galena, some sphalerite and chalcopyrite, a little tetrahedrite and bornite, and probably other metallic minerals in small amounts. The more important gangue minerals are epidote, quartz, orthoclase, sericite, and residual calcite.

The north-south fissures carry no deposits of value. At the ore horizons they commonly contain ore from the thickness of a knife blade to 2 or 3 inches, but except for this they are said to be nearly or quite barren. Even this ore appears to be distinct from the bed ore, for it is separated from the beds by distinct walls, and it carries a much higher percentage of copper and zinc. This condition suggests that the fissures were reopened and filled after the deposition of the bedded ore.

Oxidation in this deposit has been relatively slight. The ore mined in recent years is a concentrating ore of rather low grade, averaging around 8 per cent lead and about an ounce of silver per unit of lead. The ore yields considerable copper and some gold and zinc.

The mine was first worked through inclines on the dip. The main incline follows the ore to a depth of about 1,800 feet. A drain and working tunnel, through which the ore is transported by electric trains, has been driven to the ore body from a point just above the mill. A large tonnage of concentrating ore is developed in the mine and can be cheaply extracted, owing to the large size of the ore bodies and the small amount of timber required. In 1912 the capacity of the 150-ton mill was about doubled.

LION HILL.

The Lion Hill area is south of Ophir Canyon, the principal producing area being near the summit of the hill. (See Pl. XXXVIII, *A*.) Owing to the high grade of the ores, the relatively simple recovery of the metals, and the ease of development, the deposits being near the surface and in a position favorable to development by tunnels, this section of the district was early developed and for several years in the seventies was an important producer. With the exhaustion of the richer and more accessible deposits activity greatly declined and for many years operations were conducted principally by lessees. Recently several of the old properties have been combined as the Lion Hill Consolidated Co., and more systematic development of its territory has been undertaken.

The sedimentary rocks of Lion Hill are mainly limestones with interbedded calcareous shales. The lower part of the series, like that north of the canyon, is probably of Cambrian age, and for several hundred feet below the crest the rocks are of lower Carboniferous age.

The igneous rocks consist of porphyry dikes and sheets. The most important body outcrops at numerous points around the hill near the summit and appears to be a sheet, though it has not been shown to be continuous. It has been correlated by Emmons and Spurr [1] with the Eagle Hill porphyry of the Mercur district, but in several places it is coarser grained, more porphyritic, and more basic in appearance, and resembles more closely the "Birdseye" porphyry. The other porphyry is on Porphyry Hill and Porphyry Knob and is the "Birdseye" porphyry of Emmons and Spurr in the Mercur district.

The northwest-southeast anticline is beautifully exposed in Ophir Canyon. The dome structure in this anticline centering at Ophir Canyon has given the rocks a slight southward dip. The rocks here, as well as north of the canyon, have been broken by two series of fissures and faults, an east-west series generally parallel to Ophir Canyon and a north-south series about parallel with the trend of the anticline. The ore deposits are closely associated with the north-south fissures and are commonly found a short distance below the porphyry sheet. Over a considerable part of the mineralized area this porphyry is not present, but in many places the relations strongly suggest that it was once present and was removed by erosion.

Underlying the porphyry sheet and adjacent to the north-south fissures the limestone has been characteristically altered to a cherty, porous mass composed principally of silica with considerable sericite and small grains of residual calcite. This material is locally known as the "zone" rock and is associated with much of the ore.

The ores thus far developed are within a vertical distance of a few hundred feet. Well-defined fissures extend below the ore zone but are commonly open or are filled with calcite and contain no ore. The ores are almost entirely oxidized, the rich deposits containing horn silver and lead carbonate. Some ore collected by the writer contained in considerable abundance a yellow lead mineral, consisting of sulphur, lead, arsenic, iron, and in some specimens copper. Material of sufficient purity for careful quantitative study was not obtained. In some of the rich silver ore a possibly similar light-yellow sulphate fills small cavities. Plumbojarosite is rather abundant, and some of this ore is said to be rich in silver. In parts of the area, apparently especially in the northeastern, manganese oxides mixed with the iron oxides are rather abundant. The ore is characteristically a silver ore, though it contains considerable lead and gold and in places a little copper, zinc, antimony, and arsenic. The typical gangue mineral is the silicified limestone, but barite also occurs, and calcite is common. Locally, sericite, commonly called "talc," is present in considerable amounts. In some places the ore is surrounded by a gray, friable

[1] Op. cit., pp. 377-379.

mass composed largely of small quartz crystals, many of which are nearly euhedral in form and contain many small dark inclusions.

The ores of the area range in metal content from milling ores carrying a few dollars a ton to high-grade ores carrying hundreds of ounces. Considerable low-grade ore lies on the dumps and is contained in the mines, and some favorable ground in the district has never been systematically prospected. Many of the old workings are not now accessible. Some of them have been described as follows:[1]

The Zella group * * * is on the western side and near the summit of Lion Hill. * * * Three large bodies [of ore] and several smaller ones were found about 20 feet below the surface. The ore is a soft, yellow, siliceous chloride assaying several hundred dollars per ton. * * * It was impossible to ascertain, except approximately, the total product of this group, but it was estimated at $750,000. * * *

The ore [of the Monarch group] is found in a stratum of quartzite, dipping slightly northeast. There is limestone below and porphyry, in some places at least, above this stratum. * * * There are two or three large bodies * * * and several smaller ones. The ore is a porous quartz containing cavities filled with the "chloride" of the miners and some carbonate of lead. In the center of the body it is quite soft and fine but upon the edges very hard and coarse. * * * The total product to the close of the census year was $117,500.

The Douglas mine * * * is near the Monarch group, which it greatly resembles in gangue and ore. * * * Two bodies [of ore] have been found of about the same size 50 feet apart.

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CAMP FLOYD OR MERCUR DISTRICT.

HISTORY AND PRODUCTION.

By V. C. Heikes.

The Camp Floyd district is about 55 miles south of Salt Lake City, in Tooele County, adjoining the Ophir mining district. It contains three distinct camps—Mercur, the most important, in Lewiston Canyon (see Pl. XXXIX); Sunshine, about 4 miles south of Mercur in Sunshine Canyon; and West Dip (on the west dip of the anticline), about 2 miles west of Mercur near the western part of the range. The Salt Lake & Mercur Railroad, which was dismantled in 1914, connected with the Los Angeles & Salt Lake Railroad at Fairfield Junction and furnished transportation for the district. The district was first organized at the beginning of a silver excitement on April 16, 1870, and later was practically abandoned until the discovery of gold ore, which was successfully treated by cyanidation in 1891. On June 24, 1894, it was reorganized.

The early history of the district is reviewed by Huntley,[2] who says:

The Camp Floyd district is south of the Ophir district and is on the same range. It is an irregular rectangle, from 7 to 9 miles on a side, the mines themselves, however, being included within an area of a square mile. * * * The Carrie Steele mine * * * was discovered in 1873 by Leandro Steele; was worked from 1876 to July, 1879, when it was sold to the Carrie Steele Mining Co., of New York. * * * One large body of antimonial ore 20 feet thick and 60 by 70 feet in extreme width and length was found at the surface. The richest ore averaged $700 and occurred in a seam from 8 to 10 inches wide next to the roof. * * * The mill * * * was built by an English company in 1872-73 to work the ores of the Sparrowhawk mine. * * * It was purchased by the Carrie Steele Mining Co. in 1879, and ran from May 10 to August 15, 1880. * * *

The other mines of the Camp Floyd district are:

Mines of Camp Floyd.

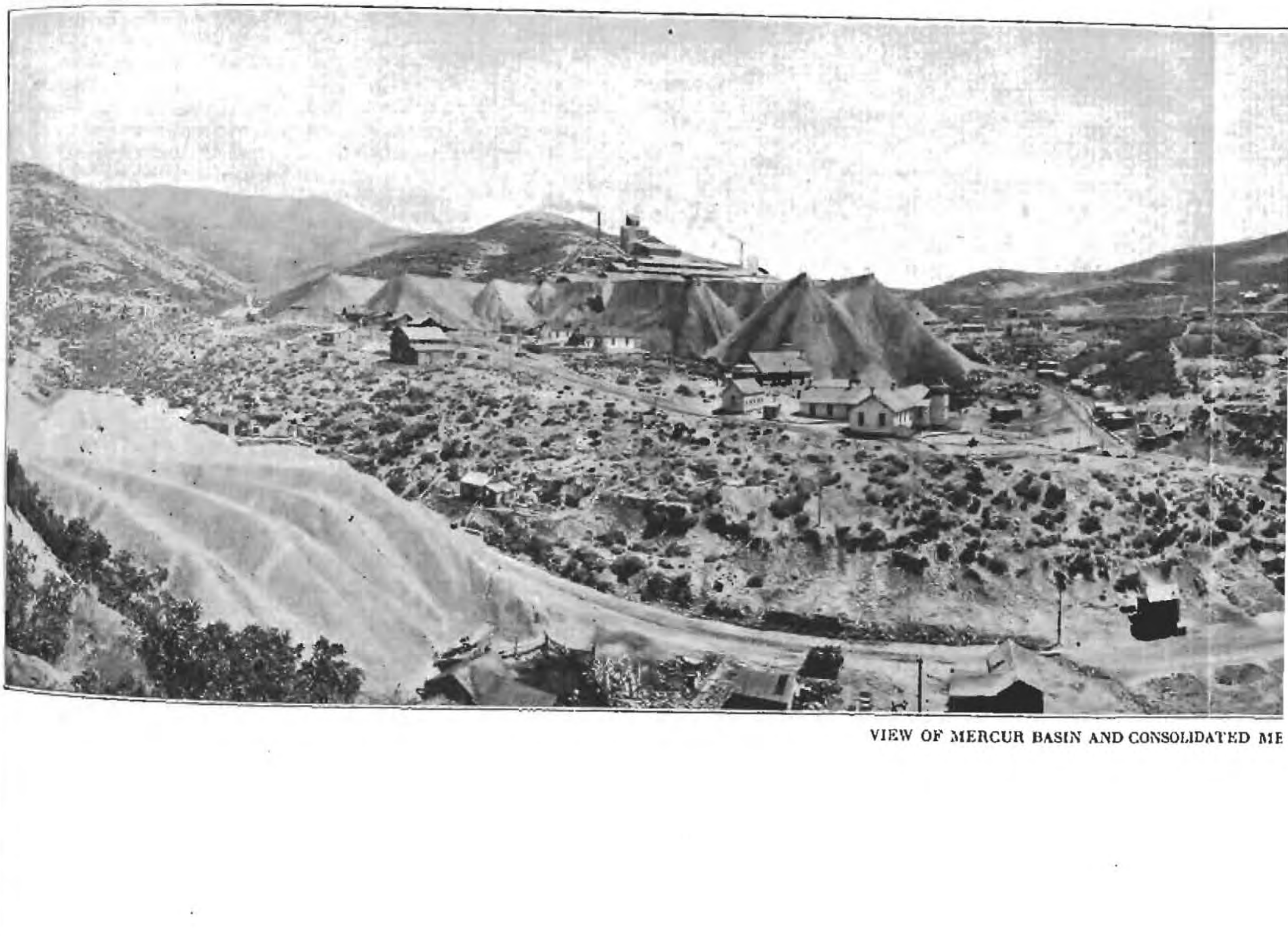
Mines.	Total length of openings.	Total product.	Remarks.
	Feet.		
Sparrow Hawk...	6,000	$300,000	Ore similar to that of the Carrie Steele.
Star of the West..	500	None.	No ore shipped.
Silver Circle.....	1,000	Small.	In 1873 many thousand dollars spent in prospecting.
Silver Cloud.....	800	....	Formerly shipped a few hundred tons of $30 ore.
Mormon Chief....	1,000	....	Little done since 1875.
Elkhorn.........	550	50,000	

The production of the district from 1871 to 1881 is estimated by Spurr[3] at 46,000 ounces of silver; the ores then worked contained no lead,

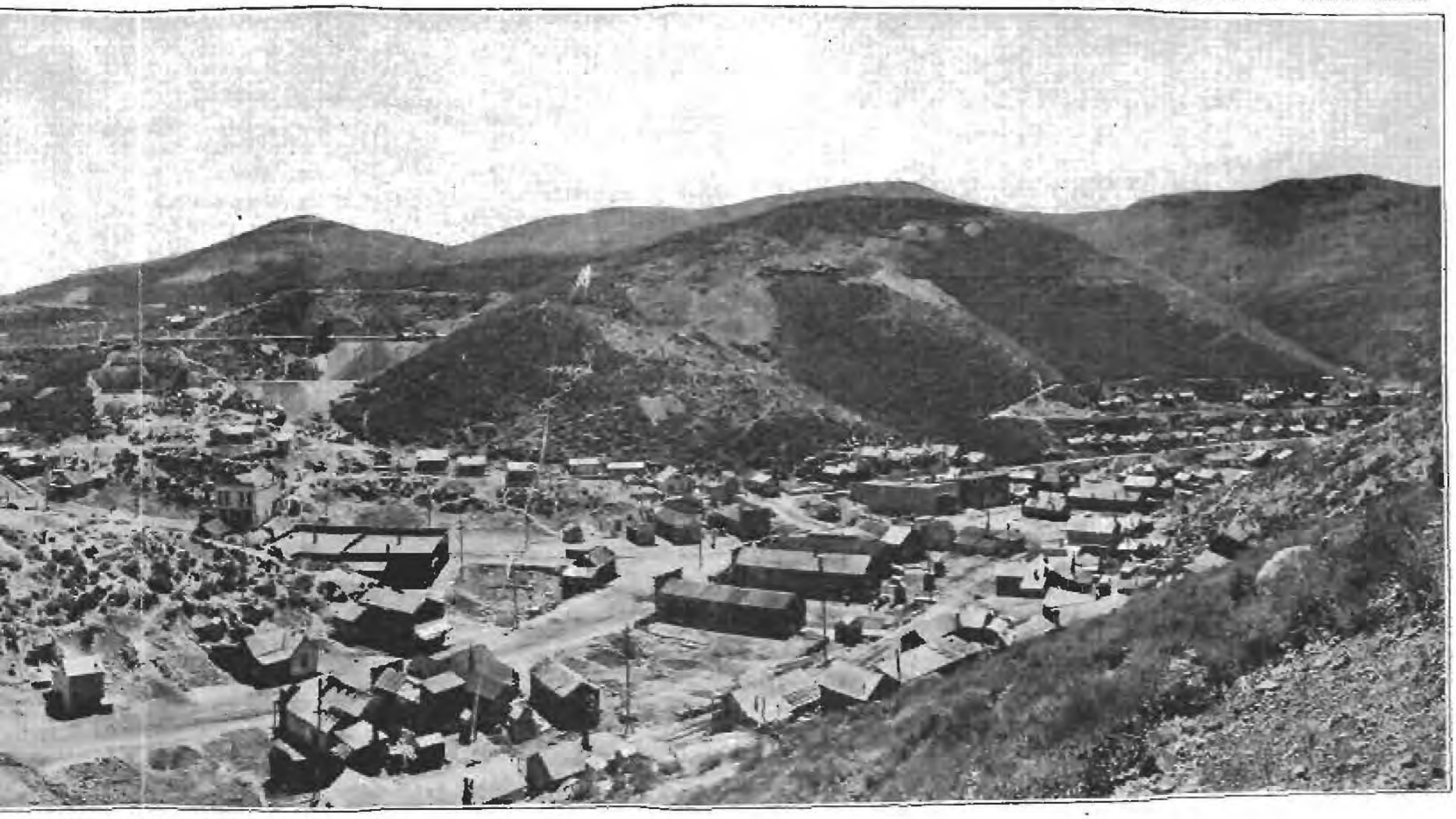
[1] Tenth Census U. S., vol. 13, p. 451, 1885.

[2] Idem, pp. 454–455.

[3] Spurr, J. E., Economic geology of the Mercur mining district: U. S. Geol. Survey Sixteenth Ann. Rept. 1894–95, pt. 2, p. 355, 1895.



VIEW OF MERCUR BASIN AND CONSOLIDATED ME



AND CONSOLIDATED MERCUR MINES MILL.

copper, nor gold. The gold production of Camp Floyd district, which became important in 1892, amounted in that and the succeeding year to about 19,000 ounces.

Gemmell[1] gives the following history of the district up to 1897:

When the district was organized on April 16, 1870, it naturally was called the Camp Floyd mining district. The first location in the district was a placer claim, located by L. Greeley on April 20, 1870. Other and similar locations followed, but placer diggings could not possibly be made to pay, for two very good reasons—lack of gold that could be panned and lack of water. The Sparrow Hawk, Last Chance, and Marion claims were among the first lode claims located. Some very rich silver ore was discovered on them (some of it going $4,000 or $5,000 to the ton) and they were soon sold to an English syndicate. The ore proved to be very "pockety," and after building a mill, spending about $700,000 and clearing only about $100,000, the company suspended operations.

Soon after the Sparrow Hawk discovery a rich strike was made in the Carrie Steele. It is said that from this pocket a few men took out about $83,000 in three months. Other strikes followed, and in 1872 and 1873 the hills were swarming with prospectors. The town of Lewiston was built on the present site of Mercur and was soon a full-fledged mining camp. * * * But no steady producing mines were found; the excitement began to die away, and Lewiston, which had grown to a town of some 1,500 people by 1880, had dwindled down to one house and to one inhabitant, Moses Manning, who remained to work out his own and others' assessments. It is estimated that during this excitement only about $350,000 were taken out and that many times that amount was expended. Machinery, supplies, and labor were all so high that it required $60 ore to pay.

On April 30, 1879, a German named Arie Pinedo located the Mercur lode, believing he had discovered a valuable vein of cinnabar and naming the claim after the German word for Mercury—Mercur. Some cinnabar was found, but not in paying quantities, and Pinedo soon abandoned the claim and left the country. Other prospectors drifted in, and about 1883 the gold ledge was discovered. The assay returns showed the yellow metal to be present in paying quantities, but after numerous attempts at panning with never a color, the prospectors gave it up.

In March, 1889, Capt. Joseph Smith * * * put up a mill on the Marion ground for the purpose of working the silver ore and tailing dump. * * * After spending $9,000 or $10,000 with no substantial result, Capt. Smith was forced to abandon the idea of making the silver ores pay. He remembered the stories of cinnabar and gold being found in the Mercur ore, sampled the vein in the summer of 1889, and got good returns in gold. All thought of mining for silver or cinnabar vanished, and during the winter of 1889-90 some work was done on the Mercur lode. A 5-ton lot of the ore was brought across the canyon to the Marion mill and treated with apparent success.

Messrs. G. S. Peyton and H. W. Brown associated themselves with Capt. Smith in March, 1890, and incorporated the Mercur Gold Mining & Milling Co. * * * Twenty-five thousand dollars were spent under the direction of Capt. Smith in building a mill near a spring at what is now called Manning, about halfway between Mercur and Fairfield station. This was an amalgamating mill, like the one previously built on the Marion ground. * * * Five thousand dollars were spent in developing the mine and fixing up the wagon road from the mine to the mill. The attempt to treat the ore by amalgamation proved a failure, however, and once again the hopes of getting any money out of the ores of Camp Floyd district were blasted. About 1,500 tons were put through the mill that by careful sampling had averaged about $18 per ton. Assays of the tailings showed an extraction of about 80 per cent, but the clean-up, instead of amounting to about $21,000, proved to be less than $5,000. Cyanide of potassium had been used for cleaning the quicksilver, and subsequent experiments proved that the gold had been dissolved and carried off by the cyanide.

About this time the successful treatment of gold ores by the cyanide process became generally known, and * * * a carload of ore was shipped to Denver for a practical test. An extraction of about 80 per cent was obtained by this test, and in the summer of 1890 the mill at Manning was remodeled and turned into a cyanide plant, by which the ore was successfully treated. Capt. Smith, having severed his connection with the Mercur mine, turned his attention to the development of the gold ledge in the Marion group of claims. He remodeled and added to the amalgamating mill previously built, and by June, 1893, started up the second cyanide plant in Mercur.

The successful treatment of the gold ores being assured, prospectors again swarmed in. Arthur Murphy and C. L. Preble located two claims on the old site of Lewiston, staked them out into town lots, and saw a new town (Mercur) grow to be about the same size as Lewistown in its palmy days—about 1,500 inhabitants. By 1897 Mercur had become a regularly organized municipality, with a water system and fire department. In 1900 the population reached 2,351, but dwindled in the next decade to 1,047 inhabitants, and in 1913 was almost entirely abandoned on the closing of operations by the Consolidated Mercur Mines Co.

The following table shows the metal output from the Camp Floyd district from the beginning of operations to the close of 1913:

[1] Gemmell, R. C., Eng. and Min. Jour., Apr. 24, 1897.

Metals produced in Camp Floyd district, by periods.[a]

Period.	Ore (short tons).	Gold.		Silver.		Total gross value recovered.
		Fine ounces.	Value.	Fine ounces.	Value.	
1871–1881 [b]				46,000	$55,936	$55,936
1890–1900	1,929,993	382,790.00	$7,912,973			[c]7,912,973
1901–1917	3,653,990	538,052.87	11,122,539	2,760	1,576	[d]11,124,115
	5,583,983	920,842.87	19,035,512	48,760	57,512	19,093,024

[a] From 1903 to 1907, 3,338 flasks of quicksilver were produced from the Sacramento mine.
[b] Spurr, J. E., Economic geology of the Mercur mining district, Utah: U. S. Geol. Survey Sixteenth Ann. Rept., pt. 2, p. 354, 1895.
[c] Average recovery, $4.10 per ton.
[d] Average recovery, $3.04 per ton.

From 1890 to the close of 1917 there were produced in the Camp Floyd district by the Mercur, Delamar, Geyser-Marion, Sacramento, Sunshine, Overland, Daisy, and La Cigale properties 5,583,513 tons of ore valued at $19,034,984. All had mills, and all except the La Cigale were successful in extracting fair values from the ores. The first five properties paid $3,881,323 in dividends to stockholders—the total amount paid during the greatest activity in the district. The old Mercur Gold Mining & Milling Co. paid dividends of $1,481,000 and the Delamar Mercur Mines Co. dividends of $689,812.99 to August 1, 1900.[1] These two companies [2] had mined up to that time 1,045,136 tons of ore at a profit of $2,181,401, or about $2.09 per ton. From August 1, 1900, to 1913, inclusive, the Consolidated Mercur Mines Co. produced gold in precipitates and bullion valued at $10,549,377, recovered from 3,291,485 tons of ore (including some tailings), or an average recovery value of $3.20 per ton of material treated at a total cost[3] of $2.82 per ton. Dividends paid aggregated $1,374,500 to July 31, 1913. The Mercur & Brickyard-Golden Gate (Delamar) property yielded 4,336,621 tons of ore, from which $16,419,541 was recovered, an average of $3.78 per ton. Dividends paid during the life of the combined properties amounted to $3,445,312.

After the first test was made on Marion and Mercur gold ore by amalgamation at the Marion mill in Lewiston Canyon, the mill erected at Manning in Fairfield Canyon for the treatment of the ore in 1890 was similarly equipped, using pan amalgamation.

In a personal communication [4] G. S. Peyton, discoverer of the process that made Mercur famous, gives the early history of the Mercur mill as follows:

> The Mercur mill was built under the advice and supervision of Joseph Smith, superintendent, at Manning in the years 1890–91 by the Mercur Gold Mining Co., organized in May, 1890. * * * The amount of gold first saved by this process of amalgamation was $3,000, representing about 15 per cent of the value of the ore. In July, 1891, a car of the $17 ore was shipped to Denver for trial by the cyanide process, which successfully extracted 92 per cent of the values. The amalgamation equipment and concentrators were then discarded, and the cyanide plant completed and started in February, 1892, on ore averaging $12 per ton in gold, of which 86 per cent was saved.

As experience was gained in the handling of the ores by the new cyanide process the mill was enlarged. * * * In 1896 the mill was treating 225 tons of ore daily, or altogether 63,480 tons for the year, averaging in value about $12 per ton in gold, of which about 80 per cent was saved. The average cost of mining and milling was about $2.80 per ton. The total amount paid in dividends up to January 1, 1897, was $600,000.

During 1897 and 1898 the Golden Gate mill was built at Mercur, and in 1900 the Delamar-Mercur Mines Co. and the Mercur Gold Mining & Milling Co. were combined and thereafter called the Consolidated Mercur Mines Co. All of the ore from the Mercur and Delamar mines was afterward treated in the Golden Gate mill, the Manning mill being used intermittently by the company and lessees for the re-treatment of tailings. The original capacity of the Golden Gate mill was 500 tons but by 1900 it was increased to 1,000 tons of ore daily.[5]

A summary of the production and costs of operations is given in the following table:

[1] Consolidated Mercur Gold Mines Co.'s annual report for the year ending June 30, 1901.

[2] Idem, p. 13.

[3] Howard, L. O., and Maguire, D., Cyanidation in the Mercur district of Utah: Pamphlet published by Salt Lake Min. Rev., p. 20, 1913.

[4] Letter from G. S. Peyton to V. C. Heikes, dated November 23, 1914. Mr. Peyton was then living at Rackerby, Cal.

[5] For a full description of the original plant on the Delamar property see Director of Mint Rept. upon production of precious metals for 1899, pp. 181–187, 1900.

Summary [a] of classified ores and tailings treated at the Consolidated Mercur Mines Co.'s mill, 1901 to 1912 (from company reports).

Production.

Year ending June 30—	Gross production.	Other income.	Tons base ore.	Tons oxidized ore.	Total tons.	Average daily tonnage.	Recovery.	Tailings loss.	Value per ton.	Mining cost.	Milling cost.	Total cost.	Profit per ton.	Dividends. Amount.	Dividends. Per cent of gross.	Per cent extraction.
1901 [b]..	$1,493,993.80	....	....	....	288,295	875	$5.19	$0.95	$6.14	....	....	$3.18	$2.01	$235,000	15.73	82.8
1902...	1,457,064.47	$1,712.50	....	....	321,626	895	4.53	1.19	5.72	$1.41	$2.09	3.50	1.03	465,000	31.91	79.2
1903...	1,321,009.63	9,277.50	....	....	335,163	931	3.84	1.21	5.05	1.30	1.58	2.88	.96	330,000	24.98	76.0
1904...	648,516.48	8,432.68	....	....	226,701	630	2.86	1.03	3.89	1.40	1.60	3.00	.04	....	......	73.5
1905...	742,291.76	12,385.15	79,703	165,323	245,026	671	2.97	.98	3.95	1.51	1.12	2.63	.34	25,000	3.37	75.3
1906...	870,887.14	9,494.77	126,538	176,268	302,806	830	2.80	.956	3.76	1.41	1.07	2.48	.32	100,000	11.48	74.5
1907...	642,843.90	14,445.10	110,069	135,100	245,169	672	2.62	.98	3.60	1.45	1.18	2.63	.01	50,000	7.78	72.8
1908...	644,353.91	15,587.25	87,492	138,737	226,229	625	2.85	.92	3.77	1.65	1.26	2.91	.06	....	......	75.6
1909...	761,235.66	13,182.10	107,607	175,262	282,269	773	2.70	.88	3.58	1.53	1.09	2.62	.08	....	......	75.4
1910...	613,148.92	12,741.12	99,447	132,190	231,631	638	2.65	.94	3.59	1.48	1.15	2.63	.02	....	......	73.8
1911...	550,695.70	7,933.49	78,897	131,622	[c] 239,190	659	2.32	.88	3.20	1.29	1.04	2.33	.01	....	......	72.3
1912...	[d] 494,133.65	3,970.98	67,816	119,776	[e] 201,652	560	2.45	.82	3.27	1.32	1.10	2.42	.03	30,000	6.01	74.9
	[f] 10,240,175.02	109,162.64	....	....	3,145,757	731	3.26	.99	4.255	[f] 1.43	[f] 1.33	2.82	.455	1,235,000	12.54	76.7

Material treated.

	1909	1910	1911	1912
Oxide ore treated ....tons...	175,262	132,190	131,622	119,776
Base ore treated ....do....	107,607	99,447	78,897	67,816
Slime plant:				
Sand ....do....	34,470	82,763	128,031	110,026
Oxidized ....do....	34,470	51,532	74,600	61,854
Base....................do....	....	31,231	53,431	48,172
Slime.......................do....	27,523	39,362	56,482	49,377
Oxidized ....do....	27,523	28,953	38,621	33,243
Base....................do....	....	10,409	17,861	16,134
Oxidized leached ....per cent..	84.3	78.1	70.7	72.3
Base leached ....do....	100.0	89.5	77.4	76.2
Total ore leached ....do....	90.2	83.0	73.2	73.7

	1909	1910	1911	1912
Ore and tails leached........per cent..	....	....	76.4	75.5
Oxidized classified.............do....	64.7	60.9	86.0	79.4
Base classified..................do....	.0	41.9	90.2	94.8
Total ore classified.............do....	21.9	52.7	87.6	85.0
Ore and tails classified ....do....	....	....	77.1	79.0
Oxidized filtered ....do....	15.7	21.9	29.3	27.7
Base filtered ....do....	.0	10.5	22.6	23.8
Total ore filtered...............do....	9.8	17.0	26.8	26.3
Ore and tails filtered...........do....	....	....	23.6	24.5
In sand tails...........cents per ton..	72	84	84	....
In slime tails....................do....	51	83	100	....

[a] Cyanidation in the Mercur district, Utah, pamphlet published by Salt Lake Min. Rev., 1913.
[b] For 11 months.
[c] Includes 28,671 tons of tailings.
[d] Corrected figures from company report.
[e] Includes 14,000 tons of tailings.
[f] For 11 years.

The character of the oxidized and base ores of the Golden Gate claims in Camp Floyd district are discussed by D. C. Jackling,[1] who says:

Locally, the ores are classified into three varieties, according to their mode of treatment:

First, "oxidized ores," consisting of a mixture in which the calcareous and siliceous varieties predominate and in which the proportion of clay and talc is insufficient to interfere with percolation.

This class of ore contains only an insignificant quantity of compounds of base elements, showing only very small fractional percentages of mercury, as cinnabar and arsenic oxidized compounds.

Second, "talcy ores," which are almost entirely clay and talc, and soft, decomposed porphyry. These ores, like the class above, are almost free from base element compounds but impossible of percolation, for the reason that on contact with water they disintegrate and settle to an almost impervious mass.

Third, "base ores," consisting of a mixture of the above classes, with the calcareous and talcose varieties predominating, and containing large quantities of base-metal sulphides. Arsenic is the chief of these, occurring as realgar, orpiment, and mispickel, in quantities sometimes as high as 50 per cent, but averaging not to exceed 2 per cent. Realgar is by far the most plentiful of the arsenic-bearing minerals, fully three-fourths of the arsenic appearing in this way. Antimony is present as stibnite. Occasional small quantities of galena occur.

Considerable quantities of iron pyrites are frequently encountered in minute crystals. Mercury is invariably present but in less quantities than in the oxidized ores. Various hydrous sulphates of iron are present, as well as oxidization products of arsenic, both simple and in combination with lime and magnesia. Some of the rarer elements, most notably tellurium, are also present, in traces only. The clays of this class of ore are invariably dark gray or black in color, due to a considerable quantity of carbon, frequently as much as 4 per cent, and in these are sometimes found organic compounds which decompose potassium cyanide very rapidly. Silver is very sparingly distributed in all classes of ore, rarely exceeding 1 ounce of silver to 10 ounces of gold. No metallic gold is visible in any of the ores until after they have been roasted, when occasional minute, irregular particles may be discovered under the microscope. All the clean, base minerals are invariably poorer in gold than the gangue with which they are associated. The clear crystals of realgar and orpiment carry none at all, or only traces, showing that the increased values of the base ore are not directly due to these base-metal minerals. The gold in whatever ore found dissolves very rapidly and completely in solutions of potassium cyanide, indicating that it is very finely divided in whatever condition it occurs, and these various facts have led me to the conclusion that the gold in these ores is present in a finely divided amorphous metallic state, having the black or brown color characteristic of the metal when in this condition, and consequently being unrecognizable under the microscope in its naturally occurring state.

[1] Director of Mint Rept. on production of precious metals for 1899, pp. 181-182, 1900.

The Marion was the first mill to be built in the Mercur area. It was part of the old Sparrow Hawk works erected for the treatment of silver ores in 1872–73, operated again on silver ores in 1880, and again, for the last time, in March, 1889, when it treated 12 tons of ore daily by pan amalgamation with poor success. In 1893 it was changed to a cyanide plant, the second in the district, and was equipped for a capacity of about 50 tons of ore daily.

In 1893 the Camp Floyd district produced between 14,000 and 15,000 ounces of gold from the Mercur and Marion mines. The scarcity of water was a decided obstacle to milling in Lewiston Canyon until a pipe line was run from Ophir district in 1893. Ore from the Marion was crushed to a size that would pass through a ⅞-inch mesh screen. The average cost of mining and milling was said to be about $2 per ton.

The next summer (1894) the Geyser Co., whose claim adjoins the Marion, commenced work on a cyanide plant with a capacity of about 100 tons of ore daily, but finished it too late in the year to permit much production. The ore took 90 hours to leach, as it was not put through screens but was simply crushed in a Gates gyratory crusher. The amount of cyanide consumed was about three-eighths of a pound per ton of ore treated, and the cost of mining and milling was said to be about $1.60 per ton.

In 1897 the Geyser-Marion interests were combined, and the Marion equipment added to the Geyser mill. The yield in gold from this property was reported to be $120,000 in 1899. The property was last operated under its old name in 1900. It was sold at sheriff's sale shortly after and worked with little success by a new company until put into the hands of a lessee, who barely succeeded in making the property pay expenses. The dividend record shows nearly $100,000 was paid to stockholders, and it is estimated that close to $500,000 in gold was recovered between 1893 and 1913.

A fourth cyanide plant was built on the Sacramento property in 1895. Success was poor at first, owing to the baseness of the ores, and thereafter only oxidized material was handled. Roasting furnaces were added to an enlarged mill in 1901 and slime tanks the fol-

lowing year. The ore treated at the mill averaged \$4.60 in gold per ton in the beginning and as low as \$3 per ton at the end of operations in 1907. The costs of mining and milling are said to have been about \$1.50 per ton, and the loss in the tailings averaged about \$1 per ton. The total value of the gold recovered during the life of the mine is estimated at \$1,500,000 and \$308,000 was paid in dividends. In addition, the Sacramento mine was for several years the most important producer of mercury in Utah.

SUNSHINE.

A few years after the first gold discoveries were made in the Camp Floyd district the Sunshine and Overland mills were built at Sunshine, 4 miles south of Mercur, to treat gold ores similar to those of Mercur. The Sunshine property was the first to be equipped with a cyanide mill, which operated from December, 1895, until October, 1896, milling about 9,000 tons of \$3 to \$4 gold ore and obtaining about \$7,000 in gold at the expenditure of several times as much. In 1898–99, according to Charles Butters,[1] another unsuccessful effort was made to treat the ore. In 1902 the mill was again started but was closed at the end of the year after producing about \$70,000 in gold bullion. In 1908 the mill was overhauled by the Boston Sunshine Gold Mining Co., which treated 125 to 150 tons of ore daily, beginning in May, 1909. By July, 1910, the ore supply of the Sunshine mine was exhausted after slightly over 50,000 tons had been treated with an average recovery of \$2.81, or a total of \$141,532, extracted at a milling cost, it is reported,[2] of 88 cents per ton, with only 20 to 40 cents left in the tailings. Dividends from these last operations aggregated \$27,261. In all the Sunshine mine is believed to have yielded about \$221,000 in gold.

The Overland Co. erected the second mill in the camp, starting operations in November, 1898, on ore from its property. It was the first mill in the district to use electrical power. Development in the upper levels of the mine was by an incline shaft and in the lower by a vertical shaft that cut the ore bed at 1,600 feet on the dip. The first ores treated ranged from \$6 to \$8 per ton in gold, but decreased to about \$2.30 a ton at the last, yielding all but 40 cents of its gold, which remained in the tailings. The mill was closed for alterations in 1899 and was started again in 1901, having been enlarged to treat 500 tons of ore daily. It is reported that the cost of mining was 85 cents and milling 25 cents per ton. The last work on the property was done under a receiver in 1904–5. No dividends were ever reported, although the property had a record of producing \$219,646 in gold from about 156,000 tons of ore.

WEST DIP.

West Dip is 4½ miles northwest of Mercur and was so named from the fact that the rocks at that point dip about 45° W., in contrast with the east dip in the Mercur camp, on the opposite side of the anticline.

Mining began in 1897, and in July, 1898, the Daisy mill, with a capacity of 112 tons a day, was erected. It is said to have produced \$75,000 in gold precipitates up to the end of 1899. In July, 1900, the Daisy mine and mill went into the hands of a receiver. The Daisy property [2] is opened by an incline shaft to the 700-foot level and had ore assaying from \$4 to \$8 per ton. The total costs of mining and milling amounted to \$3 per ton. Equipped about 1910 with modern machinery consisting of classifiers, mixers, and filter presses, the mill was the first to make a success of the West Dip ores. It was completely destroyed by fire in 1917.

In December, 1898, a mill was started on the La Cigale property, which is developed by several shafts, the deepest in 1897 being 410 feet sunk on an incline of 45°. The ore is difficult to treat, and at the end of 1899 work was abandoned. No other attempts have been reported.

TOPOGRAPHY.

By B. S. Butler.

The topography of the district is less rugged than that of the Ophir district to the north but is otherwise similar. The main canyons from Lewiston Peak cross the district toward the southwest, the direction becoming more southerly toward the southern extremity of the range. The area is thus composed of a series of southwest-trending ridges separated by canyons.

[1] Personal communication.

[2] Cyanidation in the Mercur district of Utah, pamphlet published by the Salt Lake Min. Rev., 1913.

GEOLOGY.

The geology of the Mercur district has been described by J. E. Spurr,[1] from whose report the present account is largely taken, though the writer spent several days in the district in the summer of 1912.

SEDIMENTARY ROCKS.

The sedimentary rocks are mainly limestone with some sandy and shaly beds, all being of Carboniferous age. Spurr has separated them into the "Lower Blue limestone," "Lower Intercalated series," "Great Blue limestone," containing two shale members, and "Upper Intercalated series," which he describes as follows:[2]

Lower Blue limestone.—The lowest horizon * * * is a dark blue, at times semicrystalline limestone, carrying lower Carboniferous fossils. It forms a type which is ordinarily distinct from the other limestones of the district by reason of its somewhat darker color, as well as of the granular appearance which it derives from the coarser grain and the typically semicrystalline condition. It is only in Lewiston Canyon that this lowest horizon is exposed within the district. * * * Going down the canyon from Mercur, it is met at about three-quarters of a mile from the town, rising up in the bed of the canyon with gentle northeasterly dip. It continues to form the bed of the canyon till very near the point where the canyon opens out upon the plain. At this point the slight southwestern dip has brought it down again, and it disappears below the overlying beds. In the middle of the exposure, directly in the anticlinal arch, a thickness of about 200 feet of this limestone is shown in the walls of the canyon. The bottom, however, is not seen, and so no statement in regard to the total thickness of the horizon can be made. A typical locality of this rock is at the mouth of Quartzite Gulch; this is also one of the best localities for fossils. Specimens collected at this point have been found by Mr. C. H. Schuchert to be of lower Carboniferous age.

Lower Intercalated series.—Directly above the lower limestone comes a series of alternating thin beds of limestone and calcareous sandstone, with rocks representing various stages between the mainly siliceous and the purely calcareous sediments. This series is about 600 feet thick. The thickest bed of sandstone, which has a thickness of about 100 feet, is at the bottom of the series. From this bed to the top of the series there are frequent alternations of siliceous and calcareous sediments, so closely following one another and presenting such numerous transitions from the one to the other as to show that the entire series was deposited at a comparatively uniform depth, just on the border between detrital deposits and those of organic origin. Nearly all the sandstones are more or less calcareous, and the limestones are usually siliceous.

Great Blue limestone.—Next above the Lower Intercalated series comes the formation which occupies the most of the Mercur Basin. This is a comparatively uniform, massive limestone, of a dark gray-blue color, nearly like that of the Lower limestone. It breaks with a rough, conchoidal fracture; on weathering it becomes pulverulent, greenish or pinkish, or nearly white. From its color one might suppose that it is impure, but an analysis of a typical specimen shows that in reality it is very pure, containing only a small amount of insoluble matter. It is an entirely calcareous limestone, being quite free from magnesia; the color is due to the presence of a small amount of organic material. Usually the outcrop is very fresh, the changed material being carried away as fast as produced, but in many places the alteration products have accumulated, so that the rock is more or less altered to a depth of many feet. A notable instance is seen in the cut for the railroad, just southeast of the Sunrise shaft, where the rock has been altered to a light-gray powder for a depth of 20 feet or more, apparently by surface agencies alone.

The upper limit of this rock, which may be called the Great Blue limestone, is not distinct, for it passes gradually into the series next higher up. Its thickness, therefore, may be variously estimated, according as the upper boundary is defined; the maximum, however, is about 5,000 feet.

Shale beds.—There are certain variations in the nature of the generally uniform sediments which have enough character and persistence to be noticed. Most marked among these geologically, and most important economically, are the belts of black carbonaceous and calcareous shale. These are two in number, one situated near the bottom and the other near the top of the Great Blue limestone. The upper one is the larger and the more persistent in regard to its characters. It lies about 1,000 feet from the top of the Great Blue limestone, if the latter is considered in its maximum thickness, as estimated above; but if it is considered in its minimum thickness, then the shale itself may be held to indicate its upward termination. The shale lies in a strike valley which evidently owes its existence to the more ready erosion of the shale beds, as compared with those of the harder limestones. The thickness of the belt is somewhat more than 100 feet. These shales can not be considered as typical detrital sediments; they are simply phases of the limestone. In places, especially where they have been acted on by running water, they are soft and have no great cohesion; in other places on the same horizon the rock is so hard and contains so much lime that it deserves rather the name of a shaly limestone, if considered without reference to the other localities. Specimens from this shale belt nearly always effervesce with acid. The carbonaceous matter is varying in amount but never very great. * * *

The lower shale belt lies about 2,500 feet below the upper one, and about 1,000 feet above the bottom of the Great Blue limestone. Its characters are essentially the same as the upper but are less emphasized; for, as it is not so thick, its relation to the pure limestone on both sides is closer. This shale belt averages about 25 feet in thickness, but it is variable and often becomes shaly limestone, so that it is not always possible to identify it exactly. These two shale belts carry springs which furnish the entire water supply of the Mercur district.

[1] Spurr, J. E., Economic geology of the Mercur mining district, Utah, with introduction by S. F. Emmons: U. S. Geol. Survey Sixteenth Ann. Rept., pt. 2, pp. 343–455, 1896.

[2] Idem, pp. 371–377.

Just above the larger shale belt are usually thin-bedded, somewhat shaly limestones, which are transitional between the shale and the massive blue limestone. These rocks are distinguished by the thin plates into which they split on weathering, and the by brighter reddish and greenish color of the slightly weathered specimens. There is no sharp boundary between the shaly limestones and the rocks above and below.

Upper Intercalated series.—Above the upper shale belt the rocks begin to contain arenaceous layers, separated by very thick beds of pure limestone. At a distance of about 1,000 feet above the top of the shale these sandstone beds become so common as to mark the lower limit of a new lithological series, the Upper Intercalated series. This reproduces on a larger scale the characters of the Lower Intercalated series. The rock types are nearly the same, but the individual beds are thicker and farther apart. From the bottom of the series to the top of the ridge there are probably about a dozen beds of sandstone, each of which has a thickness of 100 feet or more: yet in places the sediments seem to alternate even more closely than in the lower series. Many of the beds present for considerable distances a complete intermediate stage between sandstone and limestone, and in places layers of mainly calcareous sediments alternate very uniformly with layers which are mainly arenaceous, each layer being only a few inches thick, and the alternation being many times repeated. The thickness of this Upper Intercalated series, as estimated from its base to the summit of the ridge which divides Mercur Basin from Pole Canyon, is 5,000 or 6,000 feet. This, however, is not the top of the series, for the rocks preserve their northeasterly dip for a considerable distance down the other side of the mountain into Pole Canyon before beginning to rise again on the other side of the syncline. The total thickness, therefore, must be upward of 6,000 feet, and may be as much as 10,000 feet.

Age of the strata.—Fossils were collected from the beds in the Mercur Basin at various points, so as to represent as well as possible the entire series from the Lower Blue limestone to the Upper Intercalated series. These were submitted to Mr. Charles Shuchert, of the United States Geological Survey, who found them all to be of Carboniferous age. According to his report, the Lower Blue limestone and the Lower Intercalated series are in the lower Carboniferous, while the Upper Intercalated series is probably in the Coal Measures. The boundary between these two divisions can not be closely defined. It may be in the middle or the upper part of the Great Blue limestone, or, more probably, at the top of it. The fossils form a gradually changing series, which begins somewhere above the base of the lower Carboniferous and seems to terminate in the upper Carboniferous.[1]

ERUPTIVE ROCKS.

Spurr[2] describes the igneous rocks as follows:

In the Mercur district there are two distinct varieties of closely related eruptive rocks, which form sheets or small dikes in the Great Blue limestone. Both of these rocks belong to the class of quartz-porphyries, although they are very dissimilar in appearance.

Eagle Hill porphyry.—One of these varieties is found in greatest thickness and feshest condition in the vicinity of Eagle Hill, on the divide which separates the Mercur Basin from Sunshine and the southern end of the range. This rock in its freshest condition is nearly pure white, with a grayish, brownish, or sometimes pinkish tinge; it is compact and fine grained, and breaks with a conchoidal fracture and a rough texture. Small phenocrysts of quartz, feldspar, and biotite may often be observed, though they are never conspicuous; rarely the thin plates of biotite become nearly a quarter of an inch across.

A specimen of fresh rock shows under the microscope a finely microcrystalline groundmass, in places made up of very small spherulites, which occasionally grade into a micropegmatitic intergrowth of quartz and feldspar. Lath-shaped microlites of feldspar are very common, but the main part of the groundmass is not course enough to render the component minerals distinguishable. Phenocrysts are rare but are fresh when found. They consist, so far as observed, of quartz, biotite, and orthoclase feldspar. The quartz is in crystals or irregular grains, which show corrosion by the magma previous to the consolidation of the rock. The feldspar has crystal outlines, often rounded by corrosion, and shows no decomposition. The biotite is dark colored and strongly pleochroic; along its cleavage cracks some of the iron has separated out as oxide.

Except where the beds are thickest, the porphyry is usually considerably decomposed, and the thinner the sheet the more, as a rule, has it suffered from contact with atmospheric or other disintegrating agencies. On weathering, the rock loses cohesion and becomes a compact, very fine grained, chalky mass, so soft as to be easily impressed with the finger nail, or finally a loose powder. The weathered rocks are usually of a cream-yellow color, but they are often stained in a variety of shades—red, yellow, greenish gray, or nearly black.

The Eagle Hill porphyry seems to be split up chiefly into two principal sheets, which are well exposed on the sides of Eagle Hill. Both are in a general way parallel to the bedding of the limestone, so that they are true sheets; in places, however, the boundary cuts across the bedding at a considerable angle, which sometimes is as much as 90°. * * * When a continuous contact is mapped and plotted over a considerable distance the true relation of the limestone to the porphyry is very clearly seen.

Since the hills around Mercur are not covered by drift or alluvium, it is comparatively easy to trace continuously the line of contact of the eruptive with the sedimentary rocks. * * *

The uppermost of the two principal sheets is * * * east of Eagle Hill on the ridge south of Mercur. The top of the knob next east from Eagle Hill is of limestone, and the porphyry forms a broad belt on its sides. This sheet is probably between 250 and 300 feet thick, but it dies out rapidly, and to the northwest the outcrop does not descend from the hill, but is replaced by limestone.

The second sheet, which is estimated to be stratigraphically about 700 feet below the first, is found in its greatest thickness and with its rocks in the freshest condition on the spur between Eagle Hill and Sunrise Hill. The greatest thickness exposed here is probably upward of 300 feet, but it seems to thin with great rapidity to the north

[1] Of a series of fossil bryozoans and brachiopods from the lower shale belt, recently received, Mr. Schuchert says: "They are of the age (Burlington-Keokuk) of the Mississippian series."—S. F. Emmons.

[2] Op. cit., pp. 374-376.

and east, and to split into several small sheets. Owing to the northeast dip, these thin sheets are well exposed only in the places of deepest erosion, in this case in the lowest part of the Mercur Basin, at the head of Lewiston Canyon. Here, owing to their small thickness, they are much decomposed; they are also intimately connected with the ore deposition. There are here three small sheets, averaging about 10 or 15 feet in thickness. On the other side of the basin they seem to unite again, and the porphyry becomes temporarily thicker than in the basin. Yet it is probably now here more than 100 feet thick, and usually it is much less. The same general sheet of porphyry has been traced to the northern side of Lion Hill, at a point overlooking Ophir Canyon.

On the southern side of Eagle Hill the upper sheet occupies a considerable area; the lower sheet seems to be split up into two thin sheets, one of which runs around and joins the upper body while the other persists in the bottom of Sunshine Gulch, past the Glencoe and the Sunshine mines, till it disappears in the foothills south of Sunshine. Nearly all these outcrops are on the northeast limb of tho anticline, where the rocks dip to the northeast.

The arching of the fold causes the outcrop to describe a curve on the southeast side of Lewiston Canyon. Here the porphyry can be traced rising up above the top of the canyon wall, till with the new dip to the southwest it comes down to the bottom of the canyon again at its very mouth. On the other side of the canyon there is a part of the corresponding curve, but it does not appear to be completed, so as to join itself with the first. This may be due to a local disappearance of the sheet.

The porphyry has its greatest development around Eagle Hill, and it seems probable that somewhere in this vicinity exists the channel through which it camo up from below. The lower sheet is thickest on a line running directly from Eagle Hill to Lion Hill and appears to thin gradually from the former toward the latter, though the erosion of tho deeper valleys has removed it from much of the intermediate region. Northeastward from this line it thins rapidly, and to the northwestward it thickens.

There has been much mining development in the district since the time of Spurr's investigation and exposures in the ore zone are far more extensive, giving a correspondingly favorable opportunity for observation. The writer was informed by the management of the Consolidated Mercur Mines Co. that developments had failed to show the presence of thin porphyry sheets in connection with the ore zones and an examination of some of the best exposures in the mine failed to disclose them. Most of the rocks are much altered, and a sheet of altered porphyry might well be mistaken for an altered sediment, but it was possible to trace several supposed porphyry beds along the strike into unmistakable sedimentary rock. Moreover, several shale beds, commonly called "porphyry," carry abundant fossils that leave no doubt of their sedimentary origin.

The writer did not spend sufficient time in the district to follow out the supposed porphyry horizons in detail. At several points he was unable to recognize any porphyry and believes that porphyry at these horizons does not form continuous sheets extending out from the main masses.

Birdseye porphyry.—The other variety of porphyry, called by miners and explorers "birdseye" porphyry, is exposed on tho area of the Mercur Basin map only in the northwest corner. It forms part of two conspicuous eminences, which have been called Porphyry Hill and Porphyry Knob. This rock does not in any way resemble the porphyry just described. In its freshest condition its general color is gray. The porphyritic crystals are well developed and make up a large part of the bulk of the rock. They consist of light-gray feldspars of rather uniform size, the larger varying from an eighth to a quarter of an inch in diameter; also regularly disseminated biotite in black hexagonal prisms about an eighth of an inch in diameter, and occasional quartz crystals. These, with many smaller phenocrysts, are set in a greenish-gray groundmass. On decomposition the groundmass assumes a deep olive-green color, which becomes brownish in places; the feldspars become whiter, so that they stand out more sharply from the rest of the rock and the mica assumes a greenish-bronze color. The process of alteration of this rock is as different from that of the Eagle Hill porphyry as are the two rocks in appearance. In the beginning of the process the Eagle Hill variety breaks up into small, sharp fragments, which become dislodged and lie in great numbers on the surface above the solid rock. As disintegration proceeds the rock is finally reduced to the pulverulent state. In the birdseye porphyry, however, this is not the case. The alteration proceeds gradually throughout the rock, as it does in the disintegration of granites. The rock does not split or shell but remains firm till the process is far advanced; hence, by the time it loses its cohesiveness it is so much decomposed as to be ready to form soil. When the rock crumbles the minerals which make up the porphyritic crystals can still ordinarily be distinguished.

On the edge of the Mercur Basin the birdseye porphyry consists of a single sheet, conformable with the stratification and with the sheets of Eagle Hill porphyry. The horizon of the two porphyries is in a general way about the same, although near Porphyry Hill the sheet of the Eagle Hill variety is several hundred feet lower down than the birdseye porphyry. The latter occupies the summit of Porphyry Knob, where it has a columnar structure, which is developed by weathering. Between Porphyry Knob and Porphyry Hill erosion has worn down through the sheet and revealed the limestone beneath. The southwest slope of Porphyry Hill stands at right angles to the dip of the strata and the full thickness of the porphyry sheet is shown in section, the summit of the hill being formed of limestone strata. The porphyry outcrop followed southeast diminishes very gradually in

thickness for some distance and then terminates so abruptly as to suggest a fault. No other evidence of a fault, however, can be found, and it is certain that no movement of great importance has occurred; moreover, no outcrop of porphyry representing the other side of a fault can be found. Northwestward the porphyry can be easily traced. It runs to the east of Lion Hill and is exposed high up on the northern wall of Ophir Canyon.

The birdseye porphyry in the Mercur district, therefore, is only the edge of the main mass. It seems to have its greatest development considerably northwest of that of the Eagle Hill porphyry, although it appears at about the same horizon and on the same general topographical and stratigraphical line. It is probable, therefore, that they are genetically connected—that they represent the same general magma which ascended along the line of weakness induced by the mountain building and crystallized at different times and under varying conditions.

No evidence of value with regard to the relative age of the two varieties of porphyry has been found. In a single place—on Lion Hill—a contact between the two was found, by the side of the road which leads to the mines, but it was of such a character and the rocks were so thoroughly decomposed that no evidence could be derived from it.

STRUCTURE.

The main structural features of the Camp Floyd district are relatively simple. The west side of the range is a simple anticline striking northwest about with the trend of the range. This anticline is well exposed in Lewiston Canyon, and in Ophir Canyon to the north. Its crest in Lewiston Canyon is about 1½ miles southwest of Mercur. The Mercur Basin is therefore on the east limb of the anticline, and the camp of West Dip, as indicated by the name, is on the west limb. The same structure extends south to the limit of the range.

Faulting is of minor structural though of some economic importance. The northeast fissures are of much importance in connection with the ore deposits but have exerted little influence in the general structure of the district.

ORE DEPOSITS.

MERCUR.

The ore deposits of the Mercur area comprise silver deposits and gold deposits, both locally called "ledges." Small amounts of silver ores have been mined from the gold "ledges," and small amounts of gold from the silver "ledges," but in general the silver "ledge" carries little gold and the gold ledge ores are remarkably free from silver. The silver ores are of little commercial importance, but the gold ores have yielded largely.

SILVER DEPOSITS.

The silver "ledge" occurs at a rather definite horizon in the limestone and can be traced, with interruptions, from Lion Hill on the north to Eagle Hill on the south. At both Lion Hill and Eagle Hill the ledge appears to be associated with porphyry bodies, but between these two points its close association with porphyry is not so apparent. The ledge does, however, appear to occupy about the same horizon throughout its extent.

The typical silver ledge is a cherty material resulting from the silicification of limestone. It is resistant to erosion and usually outcrops rather prominently. In addition to cherty quartz it commonly includes considerable calcite and barite, the barite being especially abundant in the ores. Sericite is present in considerable amount in many parts of Lion Hill and in less amount in the Mercur camp.

Locally, the ledge is an ore containing, in the Mercur district, stibnite and possibly other antimony minerals; copper carbonates; scorodite, and possibly other arsenic minerals; silver in small amount, mainly as the chloride, though in the primary ore doubtless as the sulphide or some silver-antimony mineral; and a little gold.

The following is an analysis of oxidized silver ore from the Sparrowhawk mine:

Analysis of the Sparrowhawk ore.[1]

[W. F. Hillebrand, analyst.]

	Per cent.
Silicon dioxide (SiO_2)	81.70
Titanium dioxide (TiO_2)	.20
Aluminum sesquioxide (Al_2O_3)	3.24
Iron sesquioxide (Fe_2O_3)	5.41
Iron protoxide (FeO)	.28
Calcium oxide (CaO)	.44
Barium oxide (BaO)	.43
Magnesium oxide (MgO)	.16
Potassium oxide (K_2O)	1.10
Sodium oxide (Na_2O)	.12
Lithium oxide (Li_2O)	Strong trace.
Water below 110° C	.29
Water above 110° C	2.16
Sulphur trioxide (SO_3)	2.97
Phosphorus pentoxide (P_2O_5)	.05
Antimony pentoxide (Sb_2O_5)	1.02
Arsenic pentoxide (As_2O_5)	.40
Molybdenum (Mo)	Strong trace.
Tellurium (Te)	Strong trace.
	99.97

[1] Spurr, J. E., op. cit., p. 394.

The potassium and aluminum are present in very nearly the proportions for muscovite and are probably present as sericite, though some of the potassium may be present as jarosite and some of both the potassium and aluminum as alunite.

The gangue minerals of the Mercur Basin and those of Lion Hill are very similar, but the metallic constituents differ considerably, those of Lion Hill containing considerable lead, more copper, and some zinc. Neither lead or zinc are reported from the Mercur deposits. The field relations and the character of the gangue minerals leave little doubt that the silver ores of the two areas are of common origin though they differ somewhat in metal content.

The average grade of the silver ores is not known. Some rich pockets were mined, but operations were never very extensive and soon ceased indicating that the average grade was not high.

GOLD DEPOSITS.

The accompanying generalized section (fig. 41) through the ore-bearing formation of the Mercur district was furnished by the Consolidated Mercur Co. It does not represent the thickness of the different formations at any given point but is an approximate average of their thickness as they have been encountered in the mine workings.

General section.—The names given for the strata in the general section (fig. 41) of the ore-bearing formation of the Mercur area are those in common use and do not necessarily represent the character of the material; in fact, some of the beds called "porphyry" contain fossils and are generally recognized to be sedimentary.

At the base of the ore series is a massive blue limestone with beds of shaly material. These are unmineralized and practically unaltered. Overlying this is the silver ledge, which is a cherty, rather porous mass, resulting from the silicification of limestone. It carries silver, and in places is a commercial ore. Locally, notably in the anticlinal body in the Brickyard and in the Geyser mines, gold ore has been mined from the silver vein.

Overlying the silver ledge is the Magazine vein. The lower part, known as the Hard Magazine, is a cherty material, resulting from the silicification of limestone and in many places closely resembles the silver vein; commonly, however, it is more massive and does not possess the same porous character. The upper part, known as the Soft Magazine vein,

FIGURE 41.—Generalized section of ore beds in Mercur district.

is a shaly material, light colored and banded where oxidized and black where unoxidized. The hard magazine is about 20 feet thick and the soft about 7 feet. Both carry gold and have been mined.

Overlying the Magazine vein and about 30 feet of cherty material (altered limestone) that carries little gold is the shaly Apex vein which is about 8 feet thick and carries gold. It is overlain by about 4 feet of cherty material that is not ore and by 60 feet of relatively unaltered limestone.

The Mercur vein, which lies next above, is 20 to 25 feet thick. Its upper 4 feet is known as the Mercur vein "porphyry." Its lower 20 feet is separated into two parts by the Mercur vein footwall, a thin persistent layer of shaly material. The upper 12 feet is known as the Mercur vein and the lower 6 feet as the Lower Half. The Mercur vein is characterized by nodular cherty masses, which are present where the limestone is little altered and appear to be original in the limestone rather than a result of mineralization. In many places the Mercur vein has been altered to a cherty mass very similar to the silver "ledge" and the Magazine vein. The Mercur vein "porphyry," where seen in the mine, is commonly a rather massive gray rock that is soft and easily penetrated by the pick. It is of rather shaly texture and appears to be an altered sedimentary rock.

Above the Mercur vein "porphyry" is about 36 feet of limestone followed by about 6 feet of shaly fossiliferous material, gray where oxidized and black where base. This is known as the middle streak and is gold bearing. Next above is 20 feet of limestone, above which lies the highest mineralized zone—about 40 feet of shaly and siliceous material as follows: Upper vein footwall, 5 feet; Upper vein, 8 feet; Upper vein porphyry, 20 feet; shale, 8 feet. Overlying this is the massive blue limestone.

The beds are cut by a series of fissures striking east of north and dipping very steeply west. The ore shoots follow approximately the intersection of the fissures with the ore beds. The relation between ore bodies and fissures is, however, less striking in this district than in the Ophir and Stockton districts.

Alteration.—The alteration of the rocks is largely dependent on their original character. Many of the limestone beds are silicified to a cherty quartz with small amounts of a mineral resembling sericite. The shaly beds appear to have suffered less alteration though they have probably gained silica and possibly some potassium, which have formed sericite. The potassium, however, may have been originally present in the shale. Most of the ore contains also considerable barite and secondary calcite. The principal metallic minerals are pyrite, realgar with some orpiment, and cinnabar.

The following analysis is of sulphide ore from the Grasshopper shaft of the Golden Gate mine:

Analysis of Golden Gate ore.[1]

[W. F. Hillebrand, analyst.]

	Per cent.
Silicon dioxide (SiO_2)	66.42
Titanium dioxide (TiO_2)	.85
Aluminum sesquioxide (Al_2O_3)	14.85
Iron sesquioxide (Fe_2O_3) } Iron protoxide (FeO) }	.31
Iron disulphide (FeS_2)	6.60
Calcium oxide (CaO)	.35
Barium oxide (BaO)	.19
Magnesium oxide (MgO)	.83
Potassium oxide (K_2O)	2.73
Sodium oxide (Na_2O)	.13
Lithium oxide (Li_2O)	Very strong trace.
Water below 110° C.	.53
Water above 110° C.	3.65
Sulphur trioxide (SO_3)	.31
Phosphorus pentoxide (P_2O_5)	.04
Arsenic pentoxide (As_2O_5)	.41
Arsenic disulphide (As_2S_2)	1.75
Tellurium (Te)	[2]Trace (?)
	99.95

The alteration of the rock and the addition of gangue minerals in the ore shoots have not been sufficient to permit a reliable estimate of the value of the ore from its appearance. Much good ore does not perceptibly differ from waste, and it is necessary to sample and assay to determine its value. Realgar or cinnabar usually indicates good ore, but their absence is no proof of barrenness.

There is commonly a considerable difference in appearance between the oxidized and unoxidized (base) ore. The oxidized ore is generally light colored and more friable than the unoxidized; it lacks sulphides and contains sulphates, including scorodite, malanterite, jarosite, and gypsum.

[1] Spurr, J. E., op. cit., p. 424.

[2] In the opinion of Dr. Hillebrand there was tellurium in the sample analyzed, although on account of the small quantity obtained he was unable to submit it to a special test, and therefore thought best to indicate this lack of certainty by the interrogation mark.

The following is an analysis of oxidized gold ore from the stope of the Apex tunnel in the Mercur mine.[1]

Analysis of Mercur ore.

[W. F. Hillebrand, analyst.]

	Per cent.
Silicon dioxide (SiO_2)	89.24
Titanium dioxide (TiO_2)	.38
Aluminum sesquioxide (Al_2O_3)	2.02
Iron sesquioxide (Fe_2O_3)	1.45
Iron protoxide (FeO)	.62
Calcium oxide (CaO)	.95
Barium oxide (BaO)	.72
Magnesium oxide (MgO)	.23
Potassium oxide (K_2O)	.47
Sodium oxide (Na_2O)	.08
Lithium oxide (LiO)	Strong trace.
Water below 110° C	.56
Water above 110° C	1.16
Sulphur trioxide (SO_3)	.44
Phosphorus pentoxide (P_2O_5)	.08
Arsenic pentoxide (As_2O_5)	1.60
Molybdenum (Mo)	(?)
Tellurium (Te)	(?)
	100.00

Occurrence of the gold.—Gold is never visible in either the oxidized or unoxidized ores of the district, and the form in which it is present has never been positively determined, though Spurr thinks it is present as the telluride in the base ore and as free gold, though probably in some special condition, in the oxidized ore. It has been suggested by Spurr and others that the gold of the Mercur district occurs in an allotropic form that will not readily amalgamate with mercury but is attacked by chlorine and potassium cyanide. Unfortunately gold has never been found in the oxidized ores of the Mercur district in sufficient concentration to make a careful chemical examination of its condition possible.

Experiments carried on for the Consolidated Mercur Mines Co. indicate an association of the carbon of the ore with the gold. The following are the carbon content and the insoluble gold in different types of ore examined:

Association of carbon and insoluble gold in Mercur ores.

	Carbon.	Insoluble gold.
	Per cent.	
Oxidized ore	0.105	$0.40
Raw base (arsenic)	.358	.90
Pyritic base	.450	All but trace.

[1] Spurr, J. E., op. cit., p. 426.

The insoluble gold given is an average of a number of tests made on raw ore after lime oxidation by agitation of 5 pounds of ore, ground to pass 200-mesh, by air in a 2-pound cyanide solution with 25 pounds of lime. The different ores were boiled for a week, the carbon scum being skimmed repeatedly. The oxidized ore gave almost no carbon, but the pyritic base gave a large amount. An analysis of the scum gave 10.3 per cent free carbon and $9.10 gold; after agitation in potassium aurocyanide ($KAuCy_2$) solution and washing it assayed $90.60 per ton.

There is considerable concentration of gold in the carbon content of the ore, as shown by head assay after boiling: Raw pyrite base, $3.31; after boiling, $2.27.

It is of course well known that carbon will precipitate gold from solution, though no general agreement has been reached as to the cause of such precipitation; and it has also been shown [2] that in gold-silver cyanide solutions carbon precipitates gold more readily than silver, and that little silver precipitates while gold remains in solution. Spurr has shown that the gold is not particularly associated with the sulphides, and the data at hand point to its association with the carbon of the rocks.

Down the dip the character of the ore does not change notably after the sulphide ore has been reached, but the gold content decreases in a short distance from good ore to material too low in gold for commercial treatment.

The maximum distance from the outcrop to which ore has been developed is about 1,500 feet. The great bulk of the ore, however, has come from within a few hundred feet of the outcrop.

The decrease in the gold content of the ore with increasing distance from the surface suggests enrichment by surface solutions. On the other hand, the ores at or very near the surface are as rich as at any greater depth, and in the absence of an overlying leached zone it is not easy to find a source for such enrichment.

The grade of the ore is low. In 1902 it averaged $5.72 per ton, of which $1.19 was lost in the tailings. From that time the average of the ore treated has decreased till in recent years it has been as low as $3.50 per ton with 80 to 90 cents lost in tailings.

[2] Cowles, R. K., Precipitation of gold and silver by carbon: Min. and Sci. Press, vol. 105, p. 730, 1912.

The average grade of the ore mined is of course dependent on the cost of extraction and treatment, for as low-grade rock is taken as can be profitably handled.

QUICKSILVER DEPOSITS.

The Sacramento is the only mine in the district from which quicksilver has been produced in commercial quantities, and it was inaccessible when the writer visited the district. Boutwell[1] has described the deposit as follows:

> The ore is earthy cinnabar with a siliceous gangue and yields 6 per cent on an average and 80 per cent in picked samples. It occurs in bands in an altered cherty limestone adjacent to a dike and to a fracture zone. In general the portion of this limestone which bears quicksilver constitutes a lenticular shoot measuring about 10 feet in thickness, 50 feet along the strike, and 140 feet on the dip. This lens is coincident with the bedding of the limestone along the middle and major portion of its dip, but at its upper edge it bends and cuts abruptly across the bedding; while at its lower edge, on approaching the dike and fracture on its dip, it drops sharply down across the bedding, pinching out at both its upper and lower terminations to thin edges.

WEST DIP.

The deposits at West Dip are about 4½ miles west of Mercur in strata that dip rather gently west. The deposits were not being operated at the time of visit and consequently were not examined, but so far as learned from descriptions, the occurrence of the ores is similar to that at Mercur.

SUNSHINE.

The Sunshine district, about 4 miles south of Mercur, was also idle in 1912, but the occurrence of its ores is apparently similar to that at Mercur and West Dip.

GENESIS OF THE ORES.

The origin of the ores of the Camp Floyd district is not as apparent as in many districts of the State. So far as the character of the rock is concerned the location of the deposits appears to be due to the shaly strata, for the ores are associated with this zone and have not been found in the limestone or quartzite either above or below.

This association of ore with shale is susceptible of at least two interpretations: First, that the shale layers were relatively impervious to solutions and by interfering with the free circulation caused the deposition of the ores; and second, that some constituent of the shale acted as a reducing agent and precipitated the gold from the solutions. It is well known that interference by shale layers tends to cause precipitation, but in the Camp Floyd district the solutions must have passed through several shaly beds, for several ore zones lie one above another. The ability of carbon or some substance associated with it to precipitate gold from solution is also known, and the apparent association of gold with the carbonaceous matter suggests that this has been an active factor in the formation of the deposits. Moreover, as gold is ordinarily more readily precipitated than silver, a solution that contained both gold and silver might have had much of its gold and little of its silver precipitated by the carbon of the rocks.

Spurr considers that the silver deposits are distinctly older than the gold deposits and that there is no intimate relation between the two. The writer failed to find convincing evidence of this and is inclined to consider all the deposits of essentially the same age, though he is not prepared to offer a definite explanation for the difference in the metal content of the ores. In other parts of the State, where a similar difference exists, there is practically no doubt that the ore deposits are of the same age and of common origin. (See p. 180.) The ore solutions are believed to have been deep seated and associated with the general mineralization of the range. (See p. 339.)

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[1] Boutwell, J. M., Quicksilver: U. S. Geol. Survey Mineral Resources, 1906, p. 494, 1907.

EAST TINTIC MOUNTAINS.

By WALDEMAR LINDGREN and G. F. LOUGHLIN.

GENERAL FEATURES.

The East Tintic Mountains in central Utah form one of the easternmost ranges of the Great Basin. They are crossed by latitude 40° N. and longitude 112° W. They include two organized mining districts, the Tintic in the central and the North Tintic (including the Boulter district) in the northern part of the range. The boundary between these two districts is approximately marked by the Denver & Rio Grande Railroad, which extends eastward from Eureka, the largest settlement in the range. The area extending a few miles south of the railroad and east of longitude 112° 5′ W. is locally known as the East Tintic district but is here included in the Tintic district.

The Tintic district proper has long been one of the most productive in Utah and has been studied in detail. The North and East Tintic districts have only a few productive mines and have been studied only in reconnaissance. These three districts are described in a recent Survey report,[1] an abstract of which is given on pages 396–418 of this paper.

TOPOGRAPHY.

The East Tintic Mountains are maturely dissected and show evidence of typical block faulting at only a few places. The highest peaks attain elevations of over 8,000 feet. The elevation of Tintic Valley on the west is about 5,500 feet and that of Goshen Valley on the east is 4,500 feet. The range is penetrated by a few prominent transverse gulches, in the most important of which are Eureka and Mammoth, the principal settlements of the Tintic district. (See fig. 42.) Silver City, the only other active settlement, is 3 miles south of Mammoth, at the mouth of a smaller gulch. These are all reached by the Denver & Rio Grande and the Los Angeles & Salt Lake railroads. Abandoned camps and old mill and smelter sites are Diamond, south of Silver City; Homansville, northeast of Eureka; and Tintic, to the southwest in Tintic Valley.

There are no permanent streams in the East Tintic Mountains, but several springs rise in the area of igneous rocks and a group of them supplies Silver City. The water supplies of Eureka, the Denver & Rio Grande Railroad, and several mines are obtained from wells and infiltration galleries driven in surface débris over rhyolite and in the rhyolite itself. The water supply of Mammoth (including Robinson) is piped 18 miles from Cherry Creek in the West Tintic Mountains.

[1] Lindgren, Waldemar, and Loughlin, G. F., Geology and ore deposits of the Tintic mining district: U. S. Geol. Survey Prof. Paper 107, 1919.

TINTIC DISTRICT.

GEOLOGY.

GENERAL FEATURES.

The East Tintic Range is composed of Paleozoic sedimentary and Tertiary igneous rocks. (See fig. 42.) The sedimentary rocks are chiefly a quartzite over 6,000 feet thick, overlain by 6,500 to 7,000 feet of limestone, including a small amount of shale. The igneous rocks are in part intrusive rhyolite porphyry and monzonite and in part extrusive rhyolites, latites, and perhaps andesites. The sedimentary rocks for the most part form a great north-trending anticline in the western part of the North Tintic district and an accompanying syncline which appears in the Tintic district proper and the eastern part of the North Tintic district. The limb common to both these folds has steep to vertical dips and locally even overturned dips. The western limb of the anticline and the eastern limb of the syncline have prevailing dips of 30° or less. The folding east and south of the Tintic district proper is largely concealed beneath volcanic rocks, but a small part of an anticline is exposed at the head of Goshen Valley. The stratigraphy and structure are complicated by a large number of faults, the largest of which, in the Tintic district, are prevolcanic and have had little influence on the distribution and size of ore bodies.

SEDIMENTARY ROCKS.

The sedimentary rocks included Cambrian, Ordovician, Devonian, and Mississippian strata, interrupted by unconformities at or near the top of the Cambrian and at the base of the Mississippian.

CAMBRIAN SYSTEM.

The Cambrian strata include the great Tintic quartzite, over 6,000 feet thick, the shaly Ophir formation (see p. 398), and several limestones and dolomites. They range from Lower to Upper Cambrian.

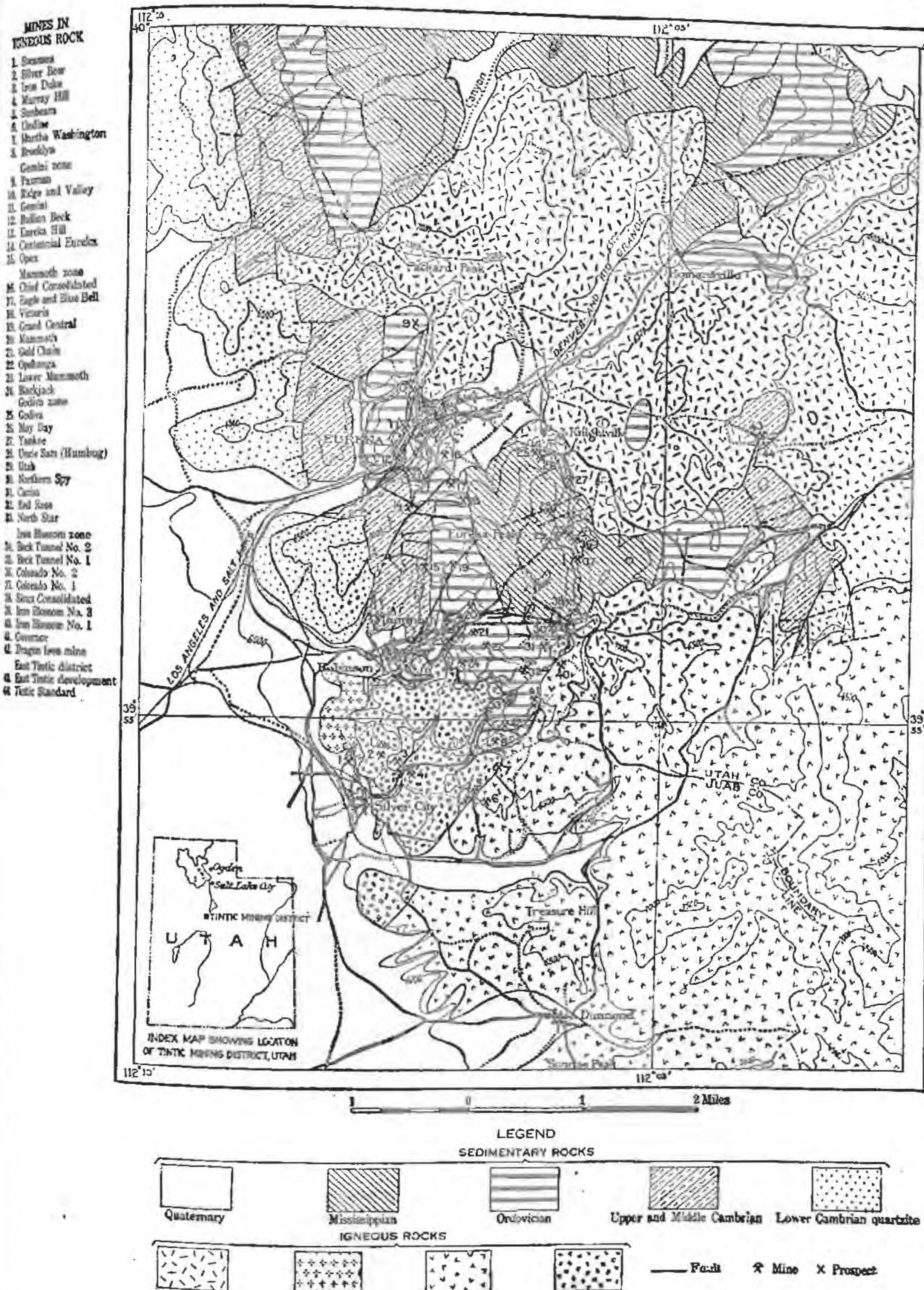

FIGURE 42.—Map showing the relation of mines to the geologic formation in the Tintic district.

Tintic quartzite.—The Tintic quartzite extends along the west front of the range from the Mammoth northward for more than 6 miles, finally pitching below the surface along the axis of the anticline. It is also exposed at a few places south of Goshen Valley and in isolated patches in the igneous area from Mammoth southward. The typical rock is grayish white to pale pink, yellow, or brown in color, of fine, even grain, and is composed almost entirely of quartz. Indications of bedding are absent in many places, owing to uniformity of composition and to excessive jointing. Conglomerate beds, however, containing mostly pebbles of vein quartz and a few of quartzite are found throughout the formation, and a few insignificant slate bands have been noted. The upper beds are less pure than the average and pass conformably but abruptly into the shale of the Ophir formation.

Three or four miles northwest of Eureka, on the west slope of the ridge, the quartzite contains a 10-foot bed, green where fresh and dark reddish-brown where weathered, that contains 18.4 per cent of iron. It has been mistaken for the gossan of a fissure vein.

Although no fossils have been found in the Tintic quartzite, it accords in stratigraphic position with other quartzite beds that are known to be Lower Cambrian. Its great thickness, over 6,000 feet, suggests, however, that its lower part may include some pre-Cambrian beds.

Ophir formation.—Above the quartzite, or along its eastern boundary, lies a band 150 to 475 feet thick of predominating gray-green shales with intercalated lenses of dark-blue argillaceous limestone, which is called the Ophir formation, after the Ophir district. Middle Cambrian fossils have been found in it 100 feet above its base. The same formation at a few other places in Utah contains Lower Cambrian fossils in its lowest beds, and the formation as a whole, therefore, appears to mark the transition from Lower to Middle Cambrian.

Beds overlying the Ophir formation.—Above the Ophir formation lies about 900 feet of prevailingly argillaceous limestone and about 710 feet of dolomite, all of Middle Cambrian age. These beds form a series of parallel north-south bands extending along the western part of the Tintic district and into the North Tintic district. They are also present in the East Tintic district, where they form the country rock around the Tintic Standard and East Tintic Development mines, and in a few small areas about 12 miles south of Mammoth. In the detailed report [1] these strata are subdivided, as follows, the lowest beds appearing at the top of the list:

Teutonic limestone, named after Teutonic Ridge, northwest of Eureka; 565 feet thick; dark bluish gray; argillaceous; in part mottled, in part striped with brown, and in part finely banded; weathers to light gray.

Dagmar limestone, named after the Dagmar property; 100 feet thick; argillaceous; dark to medium gray on fresh fracture but weathering white; very finely banded.

Herkimer limestone, named after the Herkimer property; 225 to 235 feet thick; argillaceous; dark bluish, mottled with brown; closely resembles parts of the Teutonic limestone.

Bluebird dolomite, named after Bluebird Spur west of Eureka; 200 feet thick; dark blue; spangled with short white rod-shaped and branching aggregates of dolomite.

Cole Canyon dolomite, named after Cole Canyon west of Eureka; 510 feet thick; alternating beds of dark-blue mottled or clouded dolomite and of white-weathering beds prevailingly of dolomite; contains Middle Cambrian fossils.

Dolomite beds are continuous above the Cole Canyon dolomite but are tentatively assigned to the Upper Cambrian, on the evidence of a few poorly preserved fossils. They are designated the Opex dolomite, after the Opex property, whose extensive workings are for the most part in these beds. The extensive stopes of the Centennial Eureka mine also are mostly in this formation. The rock is prevailingly dark-gray dolomite similar in character to those of Middle Cambrian age, and also includes a little light-gray dolomite, shaly limestone, a few thin beds of shale, limestone conglomerate, and quartzite. Its thickness where measured is about 400 feet but ranges from more than 400 feet down to almost nothing.

The varying character of the basal Ordovician strata, the presence in them of occasional Cambrian pebbles, and the great difference in thickness (1,227 to 3,315 feet) between

[1] Lindgren, Waldemar, and Loughlin, G. F., op. cit., pp. 27-31.

the Upper Cambrian sections, in the Tintic and in other regions in Utah, all indicate an unconformity between Upper Cambrian and Ordovician.

ORDOVICIAN SYSTEM.

The Ordovician strata include three divisions, with a total thickness of 2,300 to 2,400 feet, that extend in parallel north-south bands through the middle part of the Tintic district and into the North Tintic district. They are also prominent around Homansville and Pinyon Peak, 3 to 4 miles northeast of Eureka, and occupy an area of less than a square mile along Burriston Canyon in the East Tintic district.

Ajax limestone. — The lowest formation, named the Ajax limestone, after the old Ajax mine, is for the most part a magnesian limestone characterized by small nodules and lenses of light-gray chert. The uppermost part is very low in magnesia and grades into the middle formation. Lower Ordovician fossils are present but very scarce.

Opohonga limestone.—The Opohonga limestone, so called after the Opohonga mine, is a shaly limestone of rather light bluish-gray color, with lenticular bands and patches of yellowish or reddish brown. Its thickness, where measured between Mammoth and Eureka, is 825 feet, but it is considerably thicker in the North Tintic district. Lower Ordovician (Beekmantown) fossils are present.

Bluebell dolomite.—The upper formation is called the Bluebell dolomite after the Eagle and Bluebell mine, whose ore bodies it contains, as well as those of the Gemini, Chief Consolidated, Victoria, Grand Central, and Mammoth mines. It consists of alternating light and dark gray dolomite beds, which resemble those of the Cole Canyon (Middle Cambrian) dolomite so closely that the two formations have been confused in places, especially just north and south of Eureka, where faulting of great horizontal displacement has brought the two in line with each other. The Bluebell dolomite, however, is decidedly the thicker, ranging from about 700 to 1,100 feet, the variation being due, in part, to strike faulting and in part to an unconformity at its top. Fossils found at different places in this dolomite indicate a range in age from Lower to Upper Ordovician (Beekmantown to Richmond). The upper 400 feet, in which no fossils have been found, may be of Silurian or Lower Devonian age.

SILURIAN AND LOWER DEVONIAN SYSTEMS.

No Silurian or Lower Devonian strata have been recognized. If present, their lithologic characters are similar to those of the Ordovician dolomite, and their aggregate thickness can not be over 400 or 500 feet.

UPPER DEVONIAN SYSTEM.

Pinyon Peak limestone.—Upper Devonian fossils were found only along the upper eastern slope of Pinyon Peak, over a mile northeast of Homansville. They are contained in the Pinyon Peak limestone, a shaly limestone about 150 feet thick, similar in color and structure to the Opohonga (Ordovician) limestone.

CARBONIFEROUS (MISSISSIPPIAN) SYSTEM.

Victoria quartzite.—The lowest Mississippian strata, called the Victoria quartzite, rest unconformably upon the Devonian and Ordovician. The unconformity is marked by little or no discordance in dip, but by the variation in the age of the immediately underlying rocks and by the presence of pebbles of Ordovician dolomite in the basal beds of the Mississippian. The beds consist of more or less calcareous quartzite and conglomeratic limestone and reach a maximum of 85 feet in thickness.

Gardner dolomite. — Above the Victoria quartzite lies the Gardner dolomite (named after Gardner Canyon), which comprises 400 to 700 feet of prevailingly dolomitic dark bluish-gray beds, characterized by fossils of Lower Mississippian (Madison) age. The Gardner contains intercalated beds of black limestone and two highly carbonaceous beds, the larger of which is 100 feet thick and marks the top of the formation.

Pine Canyon limestone.—The Gardner dolomite is overlain by the Pine Canyon limestone, 1,000 feet thick, which consists for the most part of dark-blue to black and fine-grained strata, characterized by large nodules and lenses of black chert but containing in its upper part prominent beds of gray coarse-grained pure limestone, in one of which the famous ore body of the "Colorado Channel" was formed. Most of the Pine Canyon limestone, according to its fossils, is of Lower Mississippian age, but the upper 300 feet, approximately, is tentatively assigned to the Upper Mississippian.

Humbug formation.—The Pine Canyon limestone is overlain by the Humbug formation, a series of limestone, shale, and sandstone beds of Upper Mississippian age. In the Tintic district it is only 250 feet thick, but in the North Tintic district, along the western front of the range, it is very much thicker.

NOMENCLATURE.

As the sedimentary rocks are classified in more detail in Lindgren and Loughlin's report[1] than in the earlier report[2] on the district, which has been referred to in many publications since 1899, the following table may be convenient in correlating the names in both.

TOWER AND SMITH, 1899 AND 1900.	LINDGREN AND LOUGHLIN, 1919.
Humbug formation	Humbug formation.
	Pine Canyon limestone.
	Gardner dolomite.
Godiva limestone	Victoria quartzite.
	Pinyon Peak limestone.
	Bluebell dolomite.
	Opohonga limestone.
	Ajax limestone.
	Opex dolomite.
	Cole Canyon dolomite.
Mammoth (or Eureka limestone)[3]	Bluebird dolomite.
	Herkimer limestone.
	Dagmar limestone.
	Teutonic limestone.
	Ophir formation.
Tintic (or Robinson[3]) quartzite	Tintic quartzite.

IGNEOUS ROCKS.

CHARACTER AND AGE.

The greater part of the East Tintic Mountains south and east of Eureka is covered by Tertiary volcanic rocks, with which are included a few necks or stocks and dikes. They consist for the most part of rhyolite, monzonite, latite, perhaps andesite, and minor basalt. The sequence of eruptions is, so far as known, early latite or andesite, rhyolites, main latite-andesite group and monzonite, basalt. The eruptions took place long after the sedimentary rocks had been folded and faulted and eroded into topographic forms much like those of to-day.

EARLY LATITE OR ANDESITE.

The existence of biotite-augite latite or andesite earlier than the rhyolites is proved by specimens collected on the dump of a shaft whose upper part is in fluidal rhyolite. These may correspond to the lavas exposed beneath rhyolite near the Iron Blossom No. 3 mine but are too thoroughly altered to be satisfactorily identified. They cover an insignificant part of the igneous area.

RHYOLITE.

Three important areas of rhyolite and one of rhyolite porphyry were mapped during the first survey of the district. The southern rhyolite, called the Fernow rhyolite, and the northern rhyolite, unnamed, are not near the principal mining centers and are not described here. The middle rhyolite is called the Packard rhyolite, and the rhyolite porphyry the Swansea rhyolite. Besides these, there are two minor bodies of rhyolite and at least one horizon of rhyolite tuff. One of the minor rhyolite bodies, characterized by a marked fluidal structure, covers a small area east of the Iron Blossom No. 3 mine. It underlies the rhyolite tuff, which is overlain by the Packard rhyolite, and by its relations has been the means of detecting postvolcanic or "Basin Range" faulting in the northern part of the prominent ridge 3 miles east of Mammoth.

The Packard rhyolite covers an irregular area of 18 to 20 square miles north and east of Eureka. North of Eureka, at Packard Peak, which is believed to mark the center from which it erupted, the rhyolite is 800 to 1,000 feet thick and may once have been twice as thick. Several rhyolite dikes have been noted both at the surface near Packard Peak and in some of the mines near Eureka. Other dikes have been found in the East Tintic district and near Pinyon Peak. Contacts with the main latite-andesite series along its eastern and southern boundaries show the Packard rhyolite to be the older rock. The typical rock is pink to gray, in places brown or dark purple, and distinctly porphyritic. Where altered it is light greenish gray to white. The groundmass is for the most part stony (wholly or partly microcrystalline) but near the upper contact is locally a black to gray glass. The visible minerals, phenocrysts, are feldspars, quartz, and

[1] Geology and ore deposits of the Tintic mining district: U. S. Geol. Survey Prof. Paper 107, 1919.

[2] Tower, G. W., jr., and Smith, G. O., Geology and mining industry of the Tintic district, Utah: U. S. Geol. Survey Nineteenth Ann. Rept., pt. 3, pp. 601-767, 1899.

[3] Used in Tower, G. W., jr., and Smith, G. O., U. S. Geol. Survey Geol. Atlas, Tintic special folio (No. 65), 1900.

biotite. Plagioclase, as shown by the microscope, predominates over orthoclase (sanidine), although potash exceeds soda in the chemical analysis, which implies that a considerable amount of potash exists in the groundmass. Quartz occurs in glassy grains, many of them irregular and some with rather well-defined crystal outlines. Though less abundant than the feldspars it is widespread and is a distinguishing characteristic of the Packard and Swansea rhyolites as compared with the other igneous rocks of the district. Biotite forms typical six-sided crystals. Magnetite, apatite, zircon, and locally brown hornblende are minor constituents. Where the rock is altered the plagioclase is changed to sericite, calcite, and chalcedonic quartz, and the biotite to chlorite (delessite?), but the other minerals are not conspicuously changed. Chalcedony or opal, and locally tridymite, calcite, and heulandite, fill flow partings and fractures.

The Swansea rhyolite is an intrusive body nearly three-fifths of a mile long and averaging one-fourth of a mile wide, between Robinson and Silver City. A few dikes of it have been found to the north, principally in deep mine workings, and one rather large inclusion of it was found in the adjacent monzonite, which is a later intrusion. The Swansea rhyolite is similar to the Packard rhyolite in color and mineral composition but lacks the structures characteristic of extrusive rocks. It is on the whole more highly porphyritic, and its groundmass in most places is more thoroughly crystallized. Alteration to chlorite, sericite, quartz, and pyrite is prevalent. At one place, in the Swansea mine, tourmaline is present.

LATITE-ANDESITE SERIES.

So far as chemical determinations have been made the members of the latite-andesite series are all latites, but it is very possible that they include andesites also. The series covers by far the greater part of the range from the latitude of Mammoth southward. The sequence of eruptions, which has been studied in detail at only a few places, is, so far as known, (1) latite tuff and breccia erupted from an explosive vent at the west end of Volcano Ridge, just south of the area shown in figure 42; (2) augite latite erupted from the same vent; (3) monzonite porphyry and related biotite-augite latite flows erupted through the Sunrise Peak neck, 2 miles northeast of Volcano Ridge; (4) augite-hypersthene latites that may be related to the principal monzonite stock at Silver City. Besides these there are in the eastern part of the region latites characterized by brown hornblende that were probably erupted from an unknown vent.

The latite erupted from the Sunrise Peak neck is the most widespread rock in the area studied. It extends northward as far as the Iron Blossom mines, east of Mammoth, and northeastward probably as far as the edge of Goshen Valley. Near Sunrise Peak it is massive and is not readily distinguished from the rock in the neck. At greater distances its extrusive character is more marked. The fresh rock is dark-greenish or brownish gray, weathering to rusty or to chalky white. It is dense and porphyritic, containing phenocrysts of plagioclase, biotite, and a minor amount of augite. The groundmass in specimens taken from the lower part of Sunrise Peak is microscopically but completely crystalline, and consists of plagioclase, biotite, minor augite, orthoclase, quartz, and the usual minor accessory minerals. At the summit of Sunrise Peak and in the neighboring area the groundmass, as seen under the microscope, is glassy and no orthoclase or quartz is recognized. Alteration minerals are quartz, sericite, epidote, chlorite, and calcite.

Of the latites with prominent hypersthene, one well exposed on Tintic Mountain, the highest peak in the region and about 8 miles south of Mammoth, is of special interest as it covers an extensive area and represents the latest eruption in the main part of the range. It is similar in mineralogic and chemical composition to the monzonite stock at Silver City, which is younger than the stocks from other known volcanic vents. It consists of plagioclase, augite, hypersthene, and a little biotite, with microscopic magnetite and apatite in a minutely crystalline to glassy groundmass.

MONZONITE.

The monzonite forms a main stock occupying a considerable area between Mammoth and Silver City and a small area across the gulch to the south; also a minor stock a short distance to the northeast near the Carisa mine. Several associated dikes are found in the neighboring mines and in the limestone area east of

them. The monzonite is intrusive into all other rocks with which it is in contact and is economically the most important igneous rock in the district, for it is believed to mark the source of the ore deposits. Areal study shows that at the time of the monzonite intrusion the present surface around Mammoth was covered by 2,000 or 2,500 feet of volcanic rocks, which account for the relatively deep-seated character of the monzonite.

The rock where fresh is dark smoky gray to purple, but where weathered is for the most part light gray or greenish gray, with brown and pink variations. It is medium even grained to rather porphyritic. Plagioclase and augite or hornblende are the most conspicuous minerals. Orthoclase is abundant but is not readily identified without a microscope. Quartz and biotite are also conspicuous under the microscope but are only minor constituents. Most if not all the hornblende is secondary after augite and perhaps hypersthene. Alteration is of the same type as in the latites but is more intense near the more important veins.

Minor variations of the monzonite include a highly quartzose phase developed around a large quartzite inclusion, a small segregation of alkalic granite, and a syenitic phase containing aegirite-augite found at a dolomite contact near the Carisa mine.

BASALT.

Three small bodies, probably intrusive sheets, of olivine basalt were found during the earlier survey at House Butte, 8 miles south of Mammoth and 1½ miles west of Tintic Mountain. Their geologic relations are obscured by talus accumulations, but they are believed to be later than the latite-andesite series which surrounds them, and they may be the youngest of all the igneous rocks.

FAULTS.

Five periods of faulting can be distinguished in the Tintic district: (1) During the folding of the strata; (2) after folding but before volcanic activity; (3) during volcanic activity; (4) closely following volcanic activity but before mineralization; and (5) distinctly later than mineralization. These periods were not all sharply separated from one another, and along some faults movements are known to have taken place during more than one of them. In figure 42 only the largest faults are shown. Most of them trend northeast, northwest, or east. Smaller east-west faults are very abundant. Several north-south faults are known to exist but are not readily found on the surface because they coincide with the strike of the strata.

The earliest faults recognized are mostly compression faults formed by the folding forces after the shapes of the folds had been determined. They include local overthrusts and accessory east-west faults along the east boundary of the Tintic quartzite and most of the prominent faults of northeastward and northwestward trends in the limestone area. Owing to the flexible character of the shale in the Ophir formation few if any of these faults cross it. The movements of blocks along all of these faults appear to have been generally eastward, involving a considerable horizontal and some upward displacement. The largest horizontal displacement (nearly 2,000 feet) is in the fault zone that obliquely crosses Eureka Gulch. North-south faults also were probably formed at this time but are not readily distinguished on the surface. A number of east-west faults were also formed, some accessory to the strong northeast and southwest faults, others more closely related to eastward bulges along the quartzite contact.

After the folding period the tendency of the rocks, now relieved from compression, to expand, gradual loss of frictional heat, and gradual isostatic readjustment all contributed to the development of tensional or normal faulting. This faulting was chiefly north-south and east-west, and was marked by the settling of certain blocks and the tilting and convergence, or divergence, of adjacent blocks. Such faulting can be proved only where exposures are abundant and otherwise favorable for the detection of faults, but there is no reasonable doubt that they are prevalent throughout the district.

The network of faults already formed, and the general settling along them, gave conditions favorable to volcanic eruption. The pressure forcing up the lava columns, besides prying apart the strata to some extent just north of Mammoth Gulch, was sufficient to cause further movement along existing faults, as well as to produce new faults. The principal faulting at this time took place around the monzonite stock, though faulting may also have

occurred in the vicinity of Packard Peak. The principal direction of displacement along some of these faults was upward, as along the Sioux Ajax fault, whose total vertical displacement is as much as 1,500 feet, although part of this may be due to movement at some earlier period. Along other faults the horizontal component of displacement was more pronounced. To this group belong the fault trending north-northeast through the Emerald and Grand Central mines and the fault trending northward through the Opex mine, where it is known as the "Parting," and the Centennial Eureka mine, where it is called the "East Limit." Along both of these faults the eastern wall moved northward, or away from the monzonite.

There is evidence that other faults, of greater displacement than those just mentioned, were formed by the upward pressure of the rising monzonite magma and were largely obliterated by the "stoping" action of the magma, which reduced the fault blocks near the fault lines to groups of large inclusions in monzonite. Available evidence at the present surface indicates that the monzonite stock made room for itself principally by thrusting apart and faulting away the adjacent rock masses and to a less though considerable extent by "stoping."

More fissuring or faulting took place after the cessation of volcanic eruptions, and is present both in igneous and sedimentary rocks. It is attributed in part to contraction of the igneous rocks, especially the monzonite, and to the general cooling of all the rocks in the district, also to further settling movements to compensate for the great amount of lava poured out upon the surface, as well as to the isostatic readjustment that may have been going on ever since the cessation of folding. No faults of great displacement are known to have been formed at this time. The development of new, open fissures, however, as well as the reopening of certain older faults, was a large factor in determining the courses of the mineralizing solutions, whose period of activity is believed to have followed shortly after that of the monzonite intrusion.

The final period of fissuring or faulting was that during which the Basin Ranges were developed. This period can not be sharply separated from that next preceding and is known to be still in progress in some parts of Utah. Some of the Tintic ore bodies are cut by postmineral fissures or brecciated by postmineral movements along older faults, and at a few places ore bodies have been clearly displaced; but at none of these places has the amount of faulting been great enough to interfere seriously with the following ore bodies.

At least one fault zone of the Basin Range type is known to exist in the region. This is at the north end of the latite-andesite ridge, 3 to 4 miles east of Mammoth. The physiography at a few places suggests the presence of other faults of this type, especially along the range front about 5 miles northwest of Eureka, but all direct structural evidence at these places is concealed.

HISTORY AND PRODUCTION.

By V. C. Heikes.

METALLURGIC DEVELOPMENTS.

GENERAL FEATURES.

Owing to the poor transportation facilities the development of the mines in the Tintic district was not rapid until 1878, when the railroad from Salt Lake City reached Ironton, 5 miles from Eureka. However, there was considerable activity in mining the richest of the ores near the surface and shipping them to San Francisco, Cal., to Reno, Nev., to Baltimore, Md., and even to Swansea, Wales. Later, most of the ores were shipped to Argo and Pueblo, Colo., and to the Salt Lake valley smelters. The lower-grade ores were treated at mills and smelters in the district at first with indifferent success, as the reduction processes were not fully adapted to them. Ores taken from the immediate surface were handled in amalgamation plants, though entire success was prevented by the abundance of antimony in the ores, which caused the mercury to flour. This was overcome to a large extent by roasting or chloridizing.

SMELTING.

A small mill and a smelter were erected simultaneously in 1871 at Homansville, about 2½ miles east of Eureka. Owing to the refractory nature of much of the ore, milling was not a success and smelting was tried frequently. The first smelter, the Clarkson, which was begun by the Utah Smelting & Milling Co. on June 17, 1871, turned out 172 tons of silver-

lead bullion in 60 days. The ores smelted were from the Scotia, Swansea, and Eureka mines. After producing several hundred tons of lead bullion, the plant was closed and moved away in 1872. Other smelting furnaces were erected at Diamond City and ran on ores from the Showers mine and other ores obtained by purchase. Material treated contained 50 per cent of lead and $80 in silver per ton.[1] Two furnaces were erected at Goshen in the fall of 1874 and ran at intervals for six months, producing 7½ carloads of bullion and one of copper matte, but did not prove successful and were dismantled. In 1873 the Mammoth-Copperopolis built[2] a smeltery of two furnaces, each of 12 tons capacity per 24 hours, at Roseville, 6 miles from the mine, and operated it for several months, producing 126 tons of black copper, containing 90 per cent of copper and some gold and silver, worth in all $252 per ton. Early in 1882 the Mammoth (Crismon) Co.,[3] after some experimenting, erected two matting furnaces and after testing them closed down its 27-stamp mill and built additional furnaces. Eight, with a daily capacity of 8 tons of ore each, were in operation in 1882, converting 5 tons of ore into 1 ton of matte at a cost of $12 per ton of ore. The number of furnaces was increased to 14[4] early in 1884 and a refinery had nearly been completed when operations came to a standstill. The company was reported to have been heavily in debt. In the early part of 1886 some calcining furnaces, newly erected, were reported working well on Mammoth ore and were shipping matte to Argo, Colo., but in September of the same year, they were pronounced a failure. No further smelting is recorded in the district until 1908, when the Tintic Smelting Co. erected furnaces at Silver City for treating lead and copper ores from a number of the Knight mines. Before the close of the year, two lead furnaces, of a capacity of 250 tons each, were operating, and a copper furnace was about ready to be placed in operation. Two additional lead furnaces, making four in all, were added in 1909 and operated until October of that year. Although the Tintic Smelting Co. achieved technologic success, the greater economy in shipping ores to the smelters near Salt Lake led to the abandonment of local smelting.

MILLING.

The first mill was started at Homansville for the treatment of Eureka mine ores in 1872, using the amalgamation process. It had a capacity of about 25 tons of ore per day but did very little work. A second mill, erected at Homansville by an Ohio corporation called the Wyoming Mining & Milling Co., started[5] January, 1873, on ore from the old Wyoming mine,[6] afterward the Eagle (part of the Eagle and Blue Bell). This mine proved a disappointment and the company bought other mines, among them probably the Sunbeam,[7] and milled much ore. The Wyoming mill was equipped with 10 stamps, 4 amalgamating pans, and the first Stetefeldt chloridizing roaster furnace of 30-ton capacity erected in Utah. The mill is said to have been the only one at that time successful, as all the other mills used free-milling methods and failed on all ores except those from the immediate surface. Antimony, which was the chief trouble, was overcome, according to Col. Locke, by thorough chloridizing and driving off the chloride by steam. Ore of the class that the mill could treat was mined, usually in small lots, by lessees and hauled to the plant, and was milled only when sufficient ore had accumulated for a run. The mill ran in this intermittent way until 1878, when it closed because its largest shipper, the Crismon-Mammoth mine, attempted to mill its own ore. Between April 29 and June, 1877, the Wyoming mill treated ore from the Crismon-Mammoth mine aggregating 1,907 tons containing gold and silver. Of this, 547 tons assayed $11.74 in gold and 52.56 ounces of silver per ton. Most milling companies did not pay for gold previous to 1876, and as no assays were made by the miners, except for silver, the mill man had the advantage. It was this that caused the mine owners to attempt to mill their own ores. In the spring of 1874 Col. Locke took charge of the Wyoming mill, and in February, 1877, he purchased it. Afterward it was bought by the Tintic Mining & Milling Co., who reopened it on July 14, 1880. After this the charges for working the ore were $25 per ton, guaranteeing 80 per cent in bullion of the assay value of the

[1] Raymond, R. W., Statistics of mines and mining in the States and Territories west of the Rocky Mountains for 1871, p. 317, 1872.

[2] Raymond, R. W., idem for 1873, p. 274, 1874.

[3] Director of Mint Rept. upon production of precious metals, 1882, p. 257, 1883.

[4] Director of Mint Rept. upon production of precious metals, 1883, p. 628, 1884.

[5] Precious metals: Tenth Census U. S., vol. 13, p. 446, 1885.

[6] Tower, G. W., Jr., and Smith, G. O., U. S. Geol. Survey Nineteenth Ann. Rept., pt. 3, p. 739, 1899.

[7] Statement by Col. Locke to G. F. Loughlin, May 26, 1914.

silver and also of the gold if it exceeded $10 per ton. The product [1] of this mill while under Col. Locke's management, from the spring of 1874 to the spring of 1878, was $39,059 gold and $241,112 silver, recovered from 3,261 tons of ore. In 1881 this mill again began operations and worked on custom ores, mostly from the Northern Spy ore, almost continuously up to 1886.

In 1873 before purchasing the Wyoming mill the Tintic Co. built the Miller mill with 10 stamps, wet crushing, for custom work, near Diamond. Leaching [2] was unsuccessfully attempted here in the spring of 1879. The Shoebridge or Ely mill, built 6 miles south of Diamond in 1873 for custom work, had 15 stamps and 1 Aiken roasting furnace, and ran irregularly until February, 1877, when the company failed.[3] The Hunt and Douglas process was introduced in 1876. The property was bought by S. P. Ely in 1878, who ran it as a custom mill between October, 1878, and September, 1879. The process used at the mill has been described by Raymond.[4]

In 1873 the Mammoth-Copperopolis Co., at about the same time or shortly before it constructed its smelter, erected a mill at Roseville, 6 miles from the mine,[5] but soon found that the large quantity of copper in the ore impeded operations very much. The mill had a capacity of 22½ tons of ore per 24 hours.

The Crismon-Mammoth 27-stamp mill was built 8 miles south of the mine between December, 1876, and February, 1879, and was closed in 1882. In 1891 a 15-stamp mill, equipped by John Shettle to treat Mammoth ores by the lixiviation process, was treating daily 40 tons assaying 18 ounces of silver per ton, and 15 more stamps were being added.[6] This mill was sold to the Tintic Milling Co. in May, 1892, and worked Northern Spy ore averaging $20 in gold and silver.

Between 1886 and 1893 nearly all of the mines were shipping ores to the smelters, and all material not high enough in grade to warrant transportation was accumulating on the waste dumps, no water being available for milling them. In 1893, however, the Mammoth Mining Co. constructed a 20-mile pipe line from Cherry Creek and a pumping plant with a capacity of 600 gallons per minute, the whole at a reported cost of $130,000. During the same year, the construction of quartz mills was resumed, and in 1895 four pan amalgamation plants were operating in the district—Eureka Hill, 100 stamps, daily capacity 250 tons; Bullion Beck, roller mills and concentrating plant, daily capacity 200 tons; Mammoth, 60 stamps, daily capacity 180 tons; Farrell or Sioux mill, 20 stamps, daily capacity 60 tons. The Mammoth and the Farrell mills, at Robinson, operated very successfully on lower-grade ores, shipping both bullion and concentrates. The richer ores were shipped to the smelters near Salt Lake City and elsewhere. Later the smelters and ore buyers offered better prices and the railroads lower rates on some of the ores milled, making it an object to ship instead of mill, and all the milling plants were soon closed. In 1899 the shipping mines were the Mammoth, Bullion Beck, Centennial Eureka, Grand Central, Gemini, Eureka Hill, Swansea, South Swansea, Godiva, Humbug, Uncle Sam, Sioux, Sunbeam, Ajax, Star Consolidated, Four Aces, Carisa, Joe Bowers, May Day, Northern Spy, Eagle, Treasure Hill, Lower Mammoth, Tesora, Alaska, Showers Consolidated, Boss Tweed, Utah, Rabbits Foot, and Silver Park. The Tintic Iron mine shipped in 1899 nearly 600 cars of iron ore to be used as flux.

In 1905 concentration mills were built on the Godiva and Uncle Sam properties, using water piped 2 miles from Homansville. The Uncle Sam mill was also operated by the May Day Co. some time later. Attempts made by lessees of the May Day property to dry concentrate the carbonate ore by a process patented by Dietz & Keedy resulted in a very good grade of cerusite concentrates. In 1913 the old ore and tailing dump of the May Day was treated in a cyanide plant operated by lessees. In the later part of 1913 a mill was completed to treat the low-grade ores of the Knight mines (the Iron Blossom, Colorado, Beck Tunnel, Black Jack, Dragon, and Swansea) by the Knight-Christensen process of chloridizing, roasting, and leaching, which was said to be excellently adapted to a mixture of oxidized, sulphide, and siliceous material that could be formed from the ores of these mines. Before certain mechanical difficulties could be overcome the plant was destroyed by fire on April 6, 1915.

[1] Precious metals: Tenth Census U. S., vol. 13, p. 446, 1885.
[2] Idem, p. 456.
[3] Idem, p. 458.
[4] Raymond, R. W., Statistics of mines and mining in the States and Territories west of the Rocky Mountains for 1875, p. 395, 1877.
[5] Raymond, R. W., Idem for 1873, p. 274, 1874.
[6] Eng. and Min. Jour., vol. 52, Oct. 3, 1891.

Reconstruction was begun on the site of the abandoned Tintic smelter in July, 1915, by the Tintic Milling Co., newly organized and representing a consolidation of the Knight-Christensen Metallurgical Co. and the Mines Operating Co., which operated successfully for two years at Park City, using the Holt-Dern process of roasting. The new mill is equipped with one Christensen and three Holt-Dern roasters and was in experimental operation in the spring of 1916. The ores to be treated contain from 4 to 30 ounces of silver and 0.03 to 0.20 ounce of gold per ton, 1 to 8 per cent of lead, and a trace to 1.75 per cent of copper. The sulphides from the Swansea mine will provide, with the addition of powdered coal, the fuel necessary to the ore mixture in the chloridizing roast. Briefly, the process consists in roasting a mixture of ores, salt, and powdered coal; condensing the acid roaster gases in salt solution; leaching the roasted ore with this solution and precipitating the metals successively—gold and silver on copper and copper on lead; it is hoped to treat the final lead solution electrolytically.[1] Tests were made at the Eureka plant of the Utah Mineral Concentrating Co., which built a concentration plant of 100 tons daily capacity in the later part of 1914, equipped with rolls, tube mill, and Isbell concentrators. Low-grade ores from various parts of the Tintic district, and from the Chief mine especially, were intended for treatment in the plant. The plant was closed in October, 1916, and was used in 1917 as an experimental plant on ores from the Chief mines.

PRODUCTION.

TOTAL PRODUCTION.

The first of the tables on pages 408–409 shows the quantity and value, by metals, of the ore sold or treated in the Tintic district from 1869 to 1913, inclusive. The annual production is shown beginning with 1877. The second table summarizes the production by decades.

The tonnage and average metallic content of each kind of shipping product in the Tintic district from 1903 to 1917 is given in the tables on pages 406–410. The ore classification is necessarily arbitrary in part.

[1] Personal interview with Mr. George Dern, Dec. 22, 1915. For detailed article showing flow sheet of Knight-Christensen mill, with illustrations and full description of process, see Met. and Chem. Eng., p. 757, December, 1914.

DRY OR SILICEOUS ORES.

The dry or siliceous ores comprise gold and silver ores proper, fluxing ores carrying considerable quantities of iron and manganese oxides and very small quantities of gold and silver, and gold and silver bearing ores carrying lead or zinc in quantities too low to permit them to be classified as copper, lead, zinc, or mixed ores. The contributors of the dry or siliceous ores for the period were the Grand Central, Victoria, Dragon, Mammoth, Swansea, Lower Mammoth, Eagle and Blue Bell, Eureka City, Eureka Hill, South Swansea, Star Consolidated, Black Jack, Chief Consolidated, Hope, Garnet, Cornucopia, Windridge, Wyoming, Beatrice D., Mount Vernon, Iron Blossom, Brooklyn, Monterey, Gray Rocks, Centennial-Eureka, Ajax, Iron King, Shoebridge, Showers, Sunbeam, Victor, Rabbit Foot, Golden Treasure, and Tesora mines.

The Mammoth mine yielded the richest gold ores. The Dragon iron mine shipped iron-manganese ore for flux to the end of 1917. Its output ranged from 15,000 to 46,000 tons. The low average grade of this ore, estimated at about 40 cents in gold and not quite an ounce of silver per ton, largely affects the average of the crude ore in the following table:

Dry or siliceous ore and concentrates, with average metallic content, produced in Tintic district and shipped to smelters, 1903–1917.

Crude ore.

Year.	Quantity (short tons).	Gold (value per ton).	Silver (ounces per ton).	Copper (per cent).	Lead (per cent).	Average gross value per ton.
1903	65,167	$11.27	13.66	0.64	0.29	$20.65
1904	52,809	9.56	13.83	.16	.61	18.51
1905	38,637	5.62	16.90	.49	1.23	24.83
1906	80,424	6.47	10.67	.31	.73	15.76
1907	34,282	15.11	6.53	.18	.07	20.19
1908	2,951	4.05	26.61	......	.45	18.54
1909	11,320	12.85	23.25	1.16	1.21	29.00
1910	66,204	2.50	5.59	.54	.17	7.04
1911	180,878	5.40	12.84	.89	.69	15.04
1912	193,083	5.26	17.37	.85	.43	19.15
1913	122,087	3.24	13.81	.57	.35	13.66
1914	87,183	3.97	11.27	1.12	.38	13.48
1915	43,683	2.77	21.22	.76	1.04	17.18
1916	49,768	3.04	13.75	.96	.14	17.03
1917	75,439	4.99	13.88	1.13	......	22.91
Concentrates.						
1904	825	$5.09	33.70	0.18	......	$25.08

COPPER ORES.

The copper ores include those carrying over 2½ per cent of copper. A large contributor of these ores was the Centennial-Eureka mine. Other shippers of this kind of ore, named in the order of their importance, are the Carisa, Mammoth, Victor, Ajax, Laclede, Eagle & Blue Bell, Opohonga, Bullock, Lower Mammoth, Gold Chain, Iron Blossom, Dragon, Eureka Hill, Brooklyn, Star Consolidated, Minnie Moore, Tesora, Grand Central, Homestake, Snowflake, Black Jack, Bullion Beck, Showers, Monterey, Argenta, Primrose, West Morning Glory, Shoebridge, United Sunbeam, Governor, Rabbits Foot, Neibaur, and United Tintic.

Copper ore, with average metallic content, produced in Tintic district and shipped to smelters, 1903–1917.

Year.	Quantity (short tons).	Gold (value per ton).	Silver (ounces per ton).	Copper (per cent).	Lead (per cent).	Average gross value per ton.
1903	83,062	\$6.79	17.30	4.00	......	\$27.08
1904	116,838	7.78	13.24	3.55	0.003	24.54
1905	166,417	10.60	11.95	3.05	.001	27.40
1906	121,570	10.10	10.85	2.51	.028	27.21
1907	141,399	10.88	13.52	2.47	......	29.69
1908	111,194	9.99	15.47	2.39	.530	24.93
1909	119,480	8.71	12.12	2.29	.640	21.51
1910	87,334	8.25	9.68	4.08	.110	23.90
1911	69,014	5.75	12.61	5.42	.240	26.20
1912	126,079	4.67	10.99	3.69	.870	24.39
1913	146,994	4.33	8.33	2.44	.050	16.96
1914	61,377	4.90	10.13	1.94	......	15.67
1915	110,619	4.92	7.66	1.93	.009	15.56
1916	115,043	3.68	9.49	2.32	......	21.31
1917	96,844	2.63	8.74	3.20	......	27.32

LEAD ORES.

In general the crude lead ores and lead concentrates are those containing over 4½ per cent of lead. The most persistent producers of lead product of shipping grade during the last 15 years were the Bullion Beck, Eureka Hill, Gemini, Lower Mammoth, May Day, Uncle Sam, Yankee, Eagle and Blue Bell, Ridge and Valley, Beck Tunnel, Black Jack, Mammoth, East Tintic Development, Iron Blossom, Centennial-Eureka, Chief Consolidated, Colorado, Godiva, Grand Central, Sioux, Eureka City, Clift, Ajax, Tetro, Joe Bowers, Martha Washington, Showers, Victoria, Frankie, Laclede, Star Consolidated, Victor, Silver Park, South Swansea, Shoebridge, North Clift, Windridge, Utah Consolidated, Plutus Consolidated, Salvator, Carisa, Susan, Swansea, Crown Point, Diamond Queen, Neibauer, Dragon, Tintic Standard, Gold Chain, and Rabbits Foot.

Lead ore and concentrates, with average metallic content, produced in Tintic district and shipped to smelters, 1903–1917.

Year.	Quantity (short tons).	Gold (value per ton).	Silver (ounces per ton).	Copper (per cent).	Lead (per cent).	Average gross value per ton.
Crude ore.						
1903	36,206	\$1.45	33.28	0.60	15.26	\$33.89
1904	62,289	.88	25.41	.46	16.24	30.76
1905	53,307	1.82	24.03	.43	25.50	41.78
1906	102,383	1.69	23.38	.33	14.19	35.03
1907	90,267	3.08	30.64	.34	17.30	43.01
1908	52,083	3.43	43.80	.38	21.02	46.06
1909	125,923	4.22	37.15	.07	21.60	42.31
1910	143,971	3.34	27.73	.41	12.74	30.55
1911	92,067	2.80	25.11	.13	11.11	26.42
1912	92,450	2.99	24.22	.25	10.81	28.44
1913	117,562	3.16	24.73	.30	10.72	28.45
1914	132,768	2.23	22.95	.36	13.45	26.37
1915	116,647	2.04	22.08	.11	13.55	26.38
1916	159,742	1.67	19.53	.11	12.14	31.84
1917	151,878	1.38	20.63	.12	11.52	38.87
Concentrates.						
1903	416	\$2.28	38.69	......	19.86	\$39.86
1904	3,595	1.24	11.00	......	17.00	22.23
1905	1,400	5.95	20.03	......	20.10	37.06
1906	2,328	1.10	11.24	......	33.94	47.43
1907	2,593	1.11	13.87	......	37.75	44.97
1908	1,565	3.72	21.88	......	31.63	41.89
1909	881	3.28	21.90	......	30.45	40.86
1910	770	3.55	17.87	......	29.26	38.95
1911	574	2.45	15.93	......	25.20	33.57
1911 [a]	......	......	......	......	......	......
1913	58	.48	8.40	0.19	24.03	27.29
1914	22	3.68	53.45	.91	39.25	66.36
1915	155	......	27.42	......	17.80	30.64
1916	304	2.50	24.59	.19	35.52	68.02
1917 [a]	......	......	......	......	......	......

[a] None.

COPPER-LEAD ORES.

Copper-lead ores are classified after the same method as copper and lead ores. Contributors for the last 14 years were the United Sunbeam, Undine, Shoebridge, Laclede, Carisa, Windridge, Mammoth, Opohonga, Silver Queen, and Bullock. The table on page 410 gives the production and assay of this class of ore.

Quantity and value of ore sold or treated in the Tintic district, Juab and Utah counties, 1869–1917, and total metals recovered.

Year.	Ore (short tons).	Gold.		Silver.		Copper.		Lead.		Recoverable zinc.		Total value.[a]
		Fine ounces.	Value.	Fine ounces.	Value.	Pounds.	Value.	Pounds.	Value.	Pounds.	Value.	
1869-1876[b]		24,730.00	$511,215	894,000	$1,139,580	2,558,228	$699,903	7,744,000	$549,540			$2,900,238
1877		[c] 2,000.00	41,344	[c] 150,000	180,000	[cd] 313,200	59,508	[ce] 294,496	16,167			297,019
1878		[c] 2,500.00	51,680	[c] 130,000	149,500	[cd] 111,400	18,492	[c] 402,882	18,104			237,776
1879		[c] 2,500.00	51,680	[c] 250,000	280,000	[cd] 110,800	20,609	[c] 1,206,466	49,465			401,754
1880		[df] 4,419.00	91,349	[df] 181,545	208,777	[cd] 86,000	18,404	[c] 705,534	35,277			353,807
1881		[c] 2,332.00	48,207	[cg] 151,073	170,712	[cd] 300,000	54,600	[c] 451,810	21,687			295,206
1882		[c] 2,903.00	60,010	[d] 232,558	265,116	[cd] 505,800	96,608	[ce] 598,192	29,311			451,045
1883		[d] 2,000.00	41,344	[cg] 523,798	581,416	[cd] 281,885	46,511	[c] 900,000	38,700			707,971
1884	[c] 48,914	[d] 1,500.00	31,008	[cg] 619,194	687,305	[cd] 161,600	21,008	[c] 5,559,882	205,716			945,037
1885		[d] 868.00	17,943	[d] 868,925	929,750	[cd] 198,000	21,384	[c] 7,784,759	303,606			1,272,683
1886	[c] 32,143	[d] 2,300.00	47,545	[de] 825,000	816,750	[cde] 1,525,000	169,275	[ce] 5,971,066	274,669			1,308,239
1887	[c] 33,800	[d] 3,200.00	66,150	[d] 1,412,463	1,384,214	[cd] 2,000,000	256,000	[c] 6,337,991	285,210			1,991,574
1888	[c] 25,660	[d] 7,110.00	146,977	[d] 1,201,620	1,129,523	[cd] 2,200,000	369,600	[c] 5,854,261	257,587			1,903,687
1889	[c] 46,075	[d] 14,940.00	308,837	[d] 2,055,700	1,932,358	[cd] 1,870,000	252,450	[c] 9,978,559	389,164			2,882,809
1890	[c] 68,177	[d] 24,633.00	509,209	[d] 3,801,700	3,991,785	[cd] 868,960	135,558	[c] 10,881,908	489,686			5,126,238
1891	[c] 65,006	[d] 19,444.00	401,943	[d] 2,901,730	2,872,713	[cd] 688,000	88,064	[c] 13,147,645	565,349			3,928,069
1892	[c] 47,575	[d] 16,470.00	340,465	[d] 2,011,642	1,750,129	[cd] 966,777	112,146	[c] 9,431,527	377,261			2,580,001
1893		[d] 15,097.00	312,083	[d] 1,990,860	1,552,871	[cd] 320,000	34,560	[c] 7,063,209	261,339			2,160,853
1894		[d] 18,060.00	373,457	[d] 2,582,033	1,626,681	[cd] 820,000	77,900	[c] 8,056,635	265,869			2,343,907
1895		[d] 27,525.00	568,992	[d] 3,517,166	2,286,158	[cd] 1,574,000	168,418	[c] 11,283,564	361,074			3,384,642
1896		[d] 40,470.00	836,589	[d] 3,955,843	2,689,973	[cd] 3,005,000	324,540	[c] 13,217,833	396,535			4,247,637
1897		[d] 37,038.00	765,643	[d] 2,877,600	1,726,560	[c] 2,500,000	300,000	[c] 21,341,802	768,305			3,560,508
1898		[c] 38,136.00	788,341	[c] 3,389,507	1,999,809	[c] 2,073,759	257,146	[c] 29,060,841	1,104,312			4,149,608
1899		[c] 44,917.00	928,517	[c] 3,329,833	1,997,890	[c] 3,441,677	588,527	[c] 38,080,904	1,713,641			5,228,575
1900		[c] 75,355.00	1,557,726	[c] 4,809,971	2,982,182	[c] 6,052,157	1,004,658	[c] 36,840,579	1,620,985			7,165,551
1901		[c] 40,159.00	830,160	[c] 2,685,735	1,611,441	[c] 7,557,825	1,262,157	[c] 24,388,133	1,048,690			4,752,448
1902	[c] 131,574	[c] 33,344.00	689,282	[c] 2,978,394	1,578,549	[c] 5,271,921	643,174	[c] 20,266,507	830,927			3,741,932
1903	[c] 186,223	[h] 65,987.00	1,364,072	[h] 3,620,362	1,954,995	[h] 8,023,464	1,099,215	[h] 12,481,040	524,204			4,942,486
1904	[h] 262,680	[h] 71,961.00	1,487,558	[h] 3,938,630	2,254,866	[h] 9,035,720	1,129,465	[h] 22,122,312	967,851			5,839,740
1905	[h] 266,761	[h] 100,942.00	2,086,656	[h] 2,951,348	2,386,614	[h] 10,982,751	1,713,309	[h] 18,702,573	879,021			7,065,600
1906	[h] 317,576	[h] 93,125.00	1,925,066	[h] 4,610,794	3,089,232	[h] 7,321,471	1,413,044	[h] 32,022,190	1,825,265			8,252,607
1907	[h] 278,504	[h] 113,065.44	2,337,270	[h] 4,949,082	3,266,393	[h] 7,755,831	1,551,166	[h] 33,019,242	1,750,019			8,904,848
1908	[h] 260,104	[h] 63,248.58	1,307,464	[h] 4,118,440	2,182,773	[h] 5,707,786	753,427	[h] 25,045,882	1,051,927			5,295,591
1909	[h] 256,578	[h] 83,189.47	1,719,679	[h] 6,404,847	3,330,520	[h] 5,915,669	769,037	[h] 56,502,209	2,429,595			8,248,831
1910	[h] 300,631	[h] 66,289.22	1,370,320	[h] 5,222,742	2,820,281	[h] 8,993,036	1,142,115	[h] 37,553,445	1,652,352			6,985,068
1911	[h] 360,391	[h] 79,015.54	1,633,396	[h] 5,514,702	2,922,792	[h] 10,922,154	1,365,269	[h] 23,572,966	1,060,784			6,982,241
1912	[h] 423,830	[h] 91,947.86	1,900,731	[h] 7,073,104	4,349,959	[h] 13,339,126	2,200,956	[h] 24,356,041	1,096,022	3,709,737	$255,972	9,803,640
1913	[h] 400,430	[h] 68,327.87	1,412,462	[h] 5,829,484	3,521,008	[h] 9,261,867	1,435,590	[h] 26,279,312	1,156,289	3,596,544	201,406	7,726,755
1914	[h] 298,486	[h] 46,139.60	953,790	4,666,944	2,580,820	[h] 5,290,471	703,632	[h] 36,510,911	1,423,926	758,217	38,669	5,700,837
1915	[h] 293,474	[h] 44,348.98	916,775	4,370,984	2,216,089	[h] 5,357,932	937,638	[h] 32,657,018	1,534,880	3,845,058	476,787	6,082,169
1916	[h] 365,949	[h] 41,382.57	855,454	5,113,566	3,364,727	[h] 7,106,645	1,748,234	[h] 39,294,351	2,711,311	3,711,156	497,295	9,177,021
1917	[h] 392,386	[h] 42,015.98	868,547	5,558,763	4,580,421	[h] 9,117,723	2,489,138	[h] 35,078,949	3,016,789	1,182,941	120,661	11,075,556
Total[i]		1,574,942.11	32,556,936	125,271,682	83,343,232	171,493,635	27,552,435	752,049,426	35,358,411	16,803,653	1,590,790	180,401,801

[a] Average commercial prices used for each metal to make total for each calendar year.
[b] In December, 1869, West Tintic first attracted attention, and the Sunbeam mine was located, later becoming the first important producer, along with the Scotia; then the Eureka Hill, Mammoth, Shoebridge, Martha Washington, Black Dragon, Black Eagle, and Swansea, all operated between 1870 and 1876. In 1873 the Mammoth-Copperopolis (Ajax) and the Crismon-Mammoth mines were the principal producers of copper in Utah.
[c] Estimates by V. C. Heikes from a separation of the total output reported by the Director of the Mint, or given in the annual reviews of the Salt Lake Tribune and U. S. Geol. Survey Mineral Resources for 1882 to 1897. Parts of the records of some early producers were used in the estimates.
[d] Estimated by G. W. Tower and G. O. Smith, who gave table and remarks on production for 1880 to 1896 (U. S. Geol. Survey Nineteenth Ann. Rept., pt. 3, pp. 615-616, 1899): "It is thought the production of silver and gold previous to 1880 did not exceed $2,000,000. From 1880 to 1896, inclusive, the production in gold has been 201,957 ounces and in silver 28,308,092 ounces. In addition to the silver and gold, Tintic has produced a large amount of lead and copper. The only method of calculation of the lead and copper is by finding the ratio of copper to either gold or silver. As silver is more uniformly distributed in the ores than gold, this metal has been chosen as the basis of calculation. The average content of copper and lead in 240,000 tons of ores was 0.6 per cent and 13.5 per cent respectively. The ores which have furnished the basis of this calculation are the reported output of about two-thirds of the mines of the district. The content of silver of these same ores averages 52.50 ounces per ton. On this basis there are 20 pounds of copper to every 87.5 ounces of silver and 20 pounds of lead to every 3.8 ounces of silver. Applying these ratios to the total production of the camp it is shown that there should have been produced 6,470,000 pounds of copper and 74,406 tons of lead for the years from 1880 to 1896, inclusive, thus roughly estimated. These calculations, however, judged from other standpoints, seem to be somewhat low for copper and high for lead."
[e] In 1877 the Eureka Hill mine commenced to produce silver-lead heavily; in 1882 the Bullion Beck and Champion mine, a silver-lead producer; and in 1886 the Centennial-Eureka mine, although not a large producer of lead, yielded largely gold, silver, and copper.
[f] Figures originally 3,012 ounces of gold and 8,682 ounces of silver, corrected from Tenth Census U. S., vol. 13, p. 314, 1885.
[g] Tower and Smith (U. S. Geol. Survey Nineteenth Ann. Rept., pt. 3, p. 615, 1899) give, 1880 to 1888, 682 ounces; 1881, 105,354 ounces; 1883, 224,800 ounces; 1884, 612,194 ounces. These figures have been corrected from producers' reports, the Eureka Hill being the largest producer for the years given.
[h] U. S. Geol. Survey Mineral Resources, 1903 to 1917.
[i] These totals are for mine output and aggregate more than if smelters' and refiners' figures were used.

Metals produced in Tintic district, Juab and Utah counties, 1869–1917, by periods.

Period.	Gold.		Silver.		Copper.		Lead.		Recoverable zinc.		Total value.
	Fine ounces.	Value.	Fine ounces.	Value.	Pounds.	Value.	Pounds.	Value.	Pounds.	Value.	
1869–1880	36, 149. 00	$747, 268	1, 605, 545	$1, 957, 857	3, 179, 628	$816, 916	10, 353, 378	$668, 553			$4, 190, 594
1881–1890	61, 786. 00	1, 277, 230	11, 692, 031	11, 888, 929	9, 911, 245	1, 422, 994	54, 318, 428	2, 295, 336			16, 884, 489
1891–1900	332, 518. 00	6, 873, 756	31, 366, 185	21, 484, 966	21, 441, 370	2, 955, 959	187, 524, 539	7, 434, 670			38, 749, 351
1901–1910	731, 310. 71	15, 117, 527	41, 480, 374	24, 475, 664	76, 565, 474	11, 476, 109	282, 103, 533	12, 959, 851			64, 029, 151
1911–1917	413, 178. 40	8, 541, 155	38, 127, 547	23, 535, 816	60, 395, 918	10, 880, 457	217, 749, 548	12, 000, 001	16, 803, 653	1, 590, 790	56, 548, 219
	1, 574, 942. 11	32, 556, 936	125, 271, 682	83, 343, 232	171, 493, 635	27, 552, 435	752, 049, 426	35, 358, 411	16, 803, 653	1, 590, 790	180, 401, 804

Copper-lead ore, with average metallic content, produced in Tintic district and shipped to smelters, 1903–1917.

Year.	Quantity (short tons).	Gold (value per ton).	Silver (ounces per ton).	Copper (per cent).	Lead (per cent).	Average gross value per ton.
1903	388	$1.84	48.31	14.53	16.03	$81.21
1904	128	1.13	14.53	2.87	2.59	19.14
1906	485	1.49	27.11	3.82	16.00	52.90
1907	330	1.09	33.18	3.84	6.91	45.67
1908	24	.92	37.79	3.84	24.66	51.79
1909	46	.59	27.26	3.75	5.39	29.15
1910	42	1.26	10.24	7.61	16.14	43.54
1911	56	5.70	15.87	5.11	13.58	39.12
1912	472	2.53	128.14	3.49	8.13	100.18
1913	43	1.67	32.56	3.26	18.22	47.46
1914	180	.73	15.97	2.96	9.88	25.14
1915	72	.53	27.21	3.86	8.98	36.29
1916	78	3.44	52.53	3.44	11.39	70.63
1917	3	2.67	38.33	2.85	13.63	73.33

ZINC ORES.

The zinc ores are those containing 25 per cent or more of zinc, irrespective of precious-metal content. All the ore mined is a mixture of carbonate and silicate of zinc ore. Shippers of this class of ore from 1912 to 1917 were the Lower Mammoth, Uncle Sam, East Tintic Development, May Day, Gemini, Godiva, Ridge and Valley, Yankee, Chief Consolidated, Bullion Beck, Iron Blossom, Colorado, Sioux, and Empire.

Zinc ore, with average metallic content, produced in Tintic district and shipped to smelters, 1912–1917.

Year.	Quantity (short tons).	Gold (value per ton).	Silver (ounces per ton).	Lead (per cent).	Recoverable zinc (per cent).	Average gross value per ton.
1912	6,306	$0.33	1.36	1.91	29.41	$43.47
1913	6,265	....	....	....	27.91	31.26
1914	1,064	....	....	....	27.57	28.11
1915	7,029	....	.68	.34	27.35	68.53
1916	7,318	....	....	.21	25.02	67.37
1917	1,883	....	....	....	29.12	59.41

LEAD-ZINC ORES.

Most lead-zinc ores are purchased by manufacturers of pigment. In 1913, however, it was purchased by producers of spelter, some of whom save the residues for their gold, silver, and lead content. In 1913 the May Day, East Tintic Development, Tintic Standard, and Uncle Sam mines shipped an aggregate of 192 tons of ore, yielding 9.45 per cent lead and 23.29 per cent recoverable zinc, the whole valued at $34.40 per ton. The Chief, Ridge and Valley, and Showers mines were producers in 1914, 1916, and 1917.

ORE DEPOSITS.

DISTRIBUTION.

The ore deposits of the Tintic district are found in only a small part of the Tintic Range, the extensive areas of rhyolite and latite or andesite being for the most part barren. The district proper lies mainly on the western slope, measuring about 4 miles from north to south—from Silver City to a point north of Eureka—and 2 miles from east to west. (See fig. 42, p. 397.) Some outlying areas, however, contain deposits of greater or less value. On the south, prospects are found from Silver City to Diamond; on the east, about 2 miles from the divide, are the deposits of the East Tintic district; on the north about 9 miles from Eureka are the Scranton mines of the North Tintic district.

The general mineralization reaches its maximum east of Silver City, in an area of monzonite 1½ miles long and 1 mile wide; but few mines in this vicinity have yielded a great production. The monzonite and adjacent parts of the other volcanic rocks are extensively altered and impregnated with pyrite and are traversed by many fissure veins, with a general northeast trend and steep dip, some of which have yielded considerable oxidized ore. Among the mines on these veins are the Undine, Sunbeam, Martha Washington, Murray Hill, Silver Bow, Swansea, and others, the Swansea vein cutting the intrusive Swansea rhyolite near the monzonite contact. No distinct boundary separates the monzonite from the altered latite porphyry (in part at least extrusive) on the east, and the veins cut both formations. Very little work has been done on these deposits for 20 years, most of it having been stopped when large quantities of water were encountered 100 to 400 feet below the surface. The Swansea is the only mine that has been worked below water level.

The sedimentary rocks north of the monzonite are not broadly mineralized, but they contain a number of vein zones along which the limestone and dolomite are silicified over widths ranging from a few to 300 feet. Ore

outcrops in places but is neither continuous nor common and is chiefly confined to the southern part of the limestone area.

Four vein zones of northward trend have yielded the bulk of the district's production. All but one are in line with the main zone of the monzonite, but it is impossible to trace any of them across the contact at the surface. The Gemini zone, the westernmost, comprises, from north to south, the Ridge and Valley, Gemini, Bullion-Beck, Eureka Hill, and Centennial mines. The Mammoth zone, adjoining the Gemini on the east, comprises the Chief, Eagle and Blue Bell, Grand Central, Mammoth, Golden Chain, Opohonga, Lower Mammoth, and Black Jack mines. The Godiva zone, next in order, comprises the Godiva, Uncle Sam, May Day, Humbug, Utah, Northern Spy, Carisa, Red Rose, and North Star mines. Finally, the Iron Blossom zone, the easternmost, comprises the Beck tunnel, Colorado, Sioux, Iron Blossom, Governor, and Dragon mines.

The Gemini zone does not cross the limestone monzonite contact but is closely connected with the second zone in the lower workings of the Centennial Eureka and Grand Central mines. In the upper levels of Centennial Eureka and in the mines to the north the ore follows north-south fissures. In the lower levels of the Centennial Eureka it extends along the strong southward-dipping cross breaks to a depth of about 2,000 feet. South of these cross breaks extensive prospecting has failed to find ore in line with the Gemini zone.

The second or Mammoth zone has been proved to cross the monzonite contact without interruption in the Lower Mammoth mine at depths of 1,700 and 1,800 feet. A little farther north it follows a series of northerly and north-northeast fissures through the Golden Chain, Ajax, and Mammoth properties. A lateral fissure zone a little to the west carries the ore on northerly fractures through the Grand Central, Victoria, Eagle and Bluebell, and Chief mines. A west-dipping fissure in the Grand Central carries the ore down to a depth of 2,000 feet, whence it connects through the lower workings of the Centennial Eureka with the ore of the first zone.

The third and fourth zones, which are roughly parallel, lie east of the divide, about a mile east of the second zone. The third zone crosses the monzonite contact, without conspicuous outcrops, 1,500 feet southwest of the North Star mine, and extends northeastward to the Northern Spy mine, where it turns northward and has been followed to a point in the Godiva mine where the barren rhyolite overlies the limestone. The fourth zone crosses the monzonite contact at the Dragon mine, also without conspicuous outcrops, and extends northeastward to the Iron Blossom No. 3 mine, where it turns northward, losing its veinlike character, and continues along the Colorado channel, a flat replacement body evidently formed at the intersection of north-south fractures with a limestone bed particularly susceptible to replacement. In the Beck tunnel No. 2 workings, the northward course of the fourth zone ends abruptly and the ore is deflected westward along cross breaks into the Uncle Sam (Humbug) mine, where it joins the third or Godiva zone.

RELATION TO FISSURES.

The fissures in the igneous rocks in general trend N. 15°–35° E. Less commonly they trend N. 70° E., or, as the Swansea vein, a little west of north. The dip is commonly 75°–80° W. Few veins are traceable for more than half a mile.

The fractures in the sedimentary rocks (see p. 402) are many and complex and are present in all parts of the area irrespective of mineralization. They were, however, formed mostly before mineralization, and many of them antedate the volcanic period. Some of the largest faults—for instance, the great faults in Eureka Gulch and some of those in the east-west ridge to the south—had so healed at the time of mineralization that they had little or no influence on the course of the ore solutions. On the other hand, the Sioux-Ajax fault, east of Mammoth, had a marked influence on the deposits in the Iron Blossom zone.

As regards ore deposition, the most important though not the most conspicuous fractures are those that trend approximately north-south and that generally have a vertical or steep easterly dip. In the western zones they nearly or quite coincide with the upturned bedding planes. They are also abundant along the eastern zones, where the strata dip at lower angles. Both north and north-northeast

trending fractures are important in the southern part of the Mammoth zone, the ore alternating from one system to the other. East to northeast fractures that dip 50°–70° S. (known as cross breaks) are locally important and at several places form mineralized connections between parallel north-south ore bodies. The most conspicuous are the two heavily mineralized fissures in the Centennial Eureka mine, which mark the south end of the Gemini ore zone.

MINERALIZATION.

GENERAL CHARACTER.

The deposits of the district may be conveniently divided into those in igneous rocks, those in sedimentary rocks, and a small group of oxidized iron-ore deposits at or near the contact of sedimentary and igneous rocks. Contact metamorphism, indicated by alteration of the limestones to enstatite, spinel, and minor amounts of garnet, diopside, and wollastonite, is pronounced along the monzonite-limestone contact. Comparative study of the original and metamorphosed limestones proves that silica and probably alumina were the principal constituents introduced by the intruding magma, the metalliferous emanations contemporaneous with contact metamorphism having probably largely escaped into the porous volcanic rocks that then overlay much of the monzonite area. Deposits in both igneous and sedimentary rocks are characterized by the same essential mineral composition. The principal gangue minerals are quartz, usually as fine-grained jasperoid, and barite. The ore minerals are principally galena and enargite, small quantities of zinc blende, and pyrite, oxide, carbonate, or arsenate of bismuth, and subordinate tetrahedrite, famatinite, and chalcopyrite. The metals, arranged in their order of importance, are silver, lead, copper, gold, zinc, bismuth, arsenic, and antimony, but the last three are of small importance from an economic standpoint.

DEPOSITS IN IGNEOUS ROCKS.

Veins.—The deposits in the igneous rocks have been worked to shallow depths only, and operations have generally ceased at water level. Only the Swansea mine has attained a notable depth, its shaft going down 940 feet, 290 feet below water level.

The veins, which are rarely more than a few feet wide, have been formed both by filling and replacement, and the ore in some places grades into the altered country rock. The primary ore minerals, in order of abundance, are pyrite, galena, and enargite, in a gangue of quartz, much of which is well crystallized, barite, and a little microscopic alunite. Little is known of the details of the oxidation of these ores, for few of them have been worked in the last 20 years. Limonite and lead carbonate are the principal minerals, and much of the oxidized ore extracted was rich in silver. The metals of importance are silver, lead, copper, and locally gold. Silver is most abundant, as a rule, in the galena and enargite, but in the Swansea mine enough of it is said to be contained in the pyrite to make ore.

The important constituents of the ores from the mines in the igneous rocks range as follows:

Average content of ores in igneous rocks, Tintic district.

	Ounces per ton.
Gold	0.02– 0.18
Silver	12.0 –39.9
	Per cent.
Copper	0.26–11.15
Lead	.5 –24.9
Speiss [1]	.4 –11.3
Silica	16.0 –40.4
Iron	9.1 –31.0
Sulphur	12.0 –32.0
Zinc	.4 – 1.1
Lime	.0 – .9

Altered wall rock.—The wall rock of the veins is characterized by propylitic alteration. In and close to the ore-bearing veins it is completely replaced by quartz and pyrite, and locally by barite. Sericite is present, if at all, only in very minute quantity. This most intensely altered rock passes gradually into quartz-sericite-pyrite rock, in which the original porphyritic texture is preserved. This rock, bleached white on the weathered surface, is especially conspicuous along the vein zone that extends northeastward by the Sunbeam and Martha Washington mines to the Iron Blossom No. 3 mine, and is also conspicuous on some of the low hills east of the Iron Blossom No. 3 mine. At greater distances from the principal vein zones this rock passes into green or greenish-gray rock, in which the original minerals are largely replaced by sericite, chlorite, epidote, calcite, chalcedonic quartz or

[1] Speiss, in smelting, contains the arsenic and part of the sulphur, iron, and copper of the original ore.

opal, and a little pyrite. This type of alteration is very widespread.

The rather conspicuous pyrite in the quartz-sericite-pyrite rock, which amounts to 4 or 5 per cent and is accompanied by a little chalcopyrite, has given rise to the suggestion that this rock may be worked as a low-grade copper ore. Tests of the pyrite concentrates, however, show that the amount of copper is probably too small in view of the low topographic relief and the rather shallow ground-water level.

DEPOSITS IN SEDIMENTARY ROCKS.

General features.—In the sedimentary rocks, which are mainly dolomite, limestone, or shaly limestone, the character of mineralization is different. Extensive impregnation of pyrite and sericite is absent and the ore zones are marked by strong silicification, jasperoid and some barite replacing limestone or dolomite. The jasperoid in some places resembles a fine-grained quartzite, and in others, in the northern and eastern part of the district, assumes a cherty or flinty appearance. Its width ranges from a few feet to 100 and rarely to 200 feet. In the ore shoots it contains finely disseminated galena, some zinc blende and pyrite, and in places a lighter and more distinctly crystalline quartz and some barite. Other ore shoots contain much enargite and some pyrite and chalcopyrite or some famatinite or tetrahedrite. Such copper shoots usually contain a little lead, especially along the margins, abundant barite, less conspicuous jasperoid, and, when oxidized, much limonite. The lead shoots and copper shoots usually occur separately, but mixed shoots are found, for instance, in the Eureka Hill mine.

Oxidation.—The water level in the sedimentary rocks stands from 1,650 to 2,400 feet below the surface, according to the elevation of the shaft, and broadly speaking is found about 300 feet above the level of Utah Lake, at an elevation of 4,800 feet. Explorations in ore below the water level have been undertaken only in the Gemini mine.

Oxidation has thus penetrated to unusual depths, but in none of the stopes seen in 1911 to 1914 is it complete, although both galena and enargite are more abundant in the lower levels than near the surface. The principal oxidation minerals formed in the lead and zinc mines are anglesite, cerusite, plumbojarosite, smithsonite, calamine, and hydrozincite; those formed in the copper mines include a long series of copper arsenates, malachite and azurite, more rarely cuprite, and native copper. Silver in the oxidized ores takes the form of cerargyrite (horn silver) and of native metal. Some rich oxidized ores show native gold.

Most Tintic ores are soft crumbling masses of cellular and honeycombed appearance, more or less stained by limonite and oxidized copper minerals, and containing in places residual galena and enargite. Too little work has been done in depth to throw much light on oxidation processes below water level. It is certain that a rich sulphide ore 250 feet below water level in the Gemini mine shows some oxidation, having developed small cerusite crystals pierced by wires of native silver. Proustite and argentite, found sparsely in some mines, were probably deposited during the general process of oxidation in places where the supply of oxygen was scant.

In a large part of the upper zone not enough oxygen was available for complete oxidation. In those places much galena remains and much of the enargite has undergone partial oxidation, and high above water level secondary chalcocite and covellite have contemporaneously developed.

No positive conclusions have been reached as to the existence of sulphide enrichment below or at water level, but such enrichment may account for a very peculiar rich ore from the Gemini mine, which contains galena, pearceite, zinc blende, and marcasite. It occurs from 250 feet above to 250 feet below water level and is certainly later than the first mineralization.

Relation of ore bodies to country rock.—The character of the ore bodies bears a marked relation to that of the country rock. None of the main zones enter the Tintic quartzite, the Ophir shale, or the Middle Cambrian limestones below the Cole Canyon dolomite. Deposits in these formations consist of short quartz veins or lenses in quartzite and shale and veins or bunches of dolomite and calcite in the limestones, none of which are of economic importance.

The main zones pass through the metamorphic zone and through a variety of limestones

and dolomites. In the region of most intense mineralization ore has been stoped to a minor extent where the zones cut metamorphic limestone composed largely of silicates and also where they cut argillaceous or shaly limestone. The larger ore bodies, however, have replaced limestone and dolomite that contain 10 per cent or less of insoluble impurities where such beds are cut by mineralized fissures. At several places these ore bodies end abruptly against impure, dense-textured beds. The most remarkable example of this selective replacement is the "Colorado Channel" or Iron Blossom ore zone, which has replaced a single bed of coarse-grained limestone containing about 98 per cent calcium carbonate and 1 per cent magnesium carbonate for nearly a mile long along a north-south fissure zone that coincides in strike with the main synclinal axis, and has ignored fine-grained, less pure beds above and below. The coarse-grained limestone was particularly susceptible to replacement even where the ore-forming solutions had migrated long distances from their source and had been weakened by decrease of temperature, reaction with country rock, and probably dilution with meteoric water. This same type of limestone contains, besides the "Colorado Channel," the largest ore bodies in the North Tintic district and in the southern Wasatch Mountains.

Horizontal variation.—The deposits of the Tintic district show marked mineral variation with distance from the intrusive monzonite. Four zones of distinct character may be recognized:

In the monzonite, quartz in well-developed crystals is accompanied by much pyrite and some barite, galena, enargite, zinc blende, and chalcopyrite.

In the sedimentary rocks for a mile to 1½ miles north of the monzonite contact the gangue consists of fine-grained replacement quartz containing some small druses of well-crystallized quartz and much barite. The ores contain much enargite, a little pyrite, and in places tetrahedrite and famatinite. There are a few lead shoots, and the copper shoots contain a little lead. The ores also carry gold, averaging in the better grades of ore $10 to $20 a ton, and some silver, probably averaging 20 ounces to the ton.

Farther north in the same vein zones the sedimenary rocks contain principally galena and a little zinc blende and pyrite. The silver content is higher than farther south, averaging perhaps 30 to 40 ounces to the ton. There is practically no gold. The gangue minerals consist of predominant quartz in the form of an extremely fine grained cherty replacement of limestone or dolomite and of a moderate amount of barite. Few of the quartz crystals in the sparse drusy cavities are more than 1 millimeter in length. This zone continues, as far as known, for 1½ miles north of the end of the copper zone.

Farther north and east, beyond the lead-silver shoots, the mineralization becomes more feeble. The gangue minerals consist of calcite, dolomite, and a little quartz; the ore minerals comprise galena, zinc blende, and a few ounces of silver to the ton.

Gold and copper seem thus to occur on the whole near the monzonite, and lead, silver, and zinc mainly farther away. This arrangement may correspond to deposition in successively cooler zones and to a gradual spreading of the ore-forming solutions northward until they became so mingled with surface waters that their solvent power declined.

Vertical variation.—Far less marked is the variation in the composition of the ore with depth. The separation of the ore into lead and zinc shoots depends on the oxidation, the zinc migrating downward and replacing the limestone or dolomite wall rock and the oxidized lead ore forming without migration.[1] Lead and copper shoots may be found in close proximity in a single mine in the copper zone but show no definite change with depth. In some mines which in the upper levels carry only lead copper begins to appear with depth.

GENESIS.

There can be no reasonable doubt that the ores both in the igneous and in the sedimentary rocks were derived from the same source. The similarity of the mineralization, the general continuity in strike, and finally the actual tracing of one of the normal veins across the monzonite-limestone contact are sufficient proof. The deposits were probably formed by hot waters, charged with igneous emanations, which rose through fissures formed in the monzonite after its consolidation. These

[1] The genesis of the oxidized zinc ores has been described in detail by Loughlin, G. F., The oxidized zinc ores of the Tintic district, Utah: Econ. Geology, vol. 9, pp. 1-19, 1914.

waters penetrated the sedimentary rocks north of the monzonite and spread, gradually cooling and losing their power of mineralization.

The ore deposits were formed immediately after the close of volcanic activity at a depth of only a few thousand feet.

IRON-ORE DEPOSITS.

Along the contact of limestone and igneous rocks south and southeast of Mammoth there is a great deal of surface oxidation and the limestone contains irregular bodies of limonite, kaolin, and jasperoid. Small deposits of this type are found near the Black Jack shaft and in the hills a mile east of the Iron Blossom zone, but the largest is that of the Dragon iron mine.

At the surface this mine is in an open cut, about 200 by 75 feet in area and over 200 feet deep. The ore body of the pit is said to end just below the 300-foot level. Small deposits of the limonite-kaolin mixture are found in the same mine as far down as the 800-foot level. The limestone porphyry contact slopes southward and eastward beneath the porphyry, and the limonite-kaolin masses thus far found are all in the limestone, at or very near the contact.

The great body of iron ore occurs in irregular nearly vertical shoots, whose largest dimension trends approximately east or north. They are completely surrounded by masses of hard kaolin, which are penetrated along the margins by small offshoots of iron ore. The ore is a compact limonite, with perhaps some hematite, containing 55 to 57 per cent iron and 4.5 per cent silica. Much of it contains a trace of gold and as much as 2 ounces a ton of silver. Few copper stains have been observed. The arsenate of iron, pharmacosiderite, may be seen in places, but the quantity is insignificant. Isolated masses of copper-lead-silver ore in a quartz-barite gangue, found in the pit in line with the Dragon vein, are probably parts of this vein that have been later surrounded by limonite. Parts of the kaolin masses close by the iron ore are stained black by hydrous manganese oxide.

The genesis of these deposits is attributed to the downward migration of aluminum, iron, and manganese sulphates leached from a great thickness of pyritic porphyry that formerly overlay the present surface. These salts on reaching the limestone replaced it, forming kaolin, limonite, and wad. The kaolin itself was in part replaced by limonite and carried farther, thus forming the lower and lateral parts of the deposit. Rough calculation shows that the amount of pyritic porphyry was ample to supply the iron ore of even the large Dragon deposit.

NORTH TINTIC DISTRICT.

GEOGRAPHY.

The North Tintic district includes all the country in the East Tintic Range north of the Tintic and East Tintic districts. The area includes three nearly parallel ranges, the first two forming forks of the main range and the third a branch connecting with the Lake Mountains to the east.

There are no towns or villages in the district, and the only camp that has been continuously occupied is that of the Scranton mines in Barlow Canyon, one of the long transverse canyons that cut the west slope of the western range. Water is obtained in the western part of the district by wells driven in the alluvium of Rush Valley west of the mountains, and in the central and eastern parts from springs along the edge of Cedar Valley, which lies between the middle range and the Lake Mountains.

The Bolter (Boulder) district is 8 miles east of Lofgreen station on the Los Angeles & Salt Lake Railroad, in Tooele County. It is here, however, regarded as part of the North Tintic district.

GEOLOGY.

The rocks of the district are Paleozoic quartzite, shale, and limestone, overlain at a few places by small masses of extrusive andesite and cut by a few dikes of rhyolite and monzonite porphyry. Their stratigraphic succession and structural relations are generally the same as in the Tintic district proper, except that a rather prominent quartzite, absent in the Tintic district, has been found in the Middle Cambrian limestone near the Hot Stuff prospect. The western and middle ranges are parts of a great anticline with gently dipping western and steeply dipping eastern limbs. The northward-pitching axis of the anticline extends along Broad Canyon, which separates the two ranges. The axis

of the syncline, which is the dominant structural feature of the Tintic district proper, extends along Cedar Valley, its east limb forming the eastern part of the three ranges of the North Tintic district. Owing to these folds upper and lower Mississippian limestones form the western, Ordovician the central, and Cambrian the eastern part of the western range; the same formations in reverse order form the middle range; and the Mississippian, underlain by 150 feet of Devonian shaly limestone, forms the summit and central part of Pinyon Peak (the only part of the eastern range to be considered), and the Ordovician the remainder, except for a small amount of Cambrian at the east base.

The fissuring and faulting which characterize the Tintic district persist in the North Tintic district. Faults of considerable offset have been noted but have not been studied systematically. Premineral faults of large displacement are not, so far as noted, closely associated with ore bodies. One postmineral fault trends northward through the Scranton mine but has not been found to displace ore bodies of any importance. The most prominent mineralized fissures trend north to N. 15° E., rarely east, and are associated with oblique branches or cross fissures, also mineralized.

HISTORY AND PRODUCTION.

By V. C. Heikes.

The North Tintic district is in Tooele and partly in Juab County, in the Tintic Mountains, 6 to 10 miles northwest of Eureka. The producing mines are in Tooele County. Ore shipments are made from Delmonte, a station on the Los Angeles & Salt Lake Railroad, about 3 miles west of the mines. The name of the district was formerly Oasis but was changed to Caledonia in 1875 and to North Tintic in 1879. The production previous to 1902 is not accurately known. However, the New Bullion [1] property, worked by lessees about 1897, produced from surface ores $35,000 net in lead and silver. The largest producer of the district is the Scranton mine, which yielded oxidized lead ores between 1902 and 1905 and began the shipment of oxidized zinc and lead-zinc ores in 1906. The following table gives statistics collected by the U. S. Geological Survey to the end of 1917:

[1] Report of New Bullion Mining Co. by E. W. Clark and others, Ophir, Utah, 1906.

Metals produced in the North Tintic district, 1902–1917.

Year.	Ore (short tons).	Gold.		Silver.		Copper.		Lead.		Recoverable zinc.		Total value.
		Fine ounces.	Value.	Fine ounces.	Value.	Pounds.	Value.	Pounds.	Value.	Pounds.	Value.	
1902	352			526	$279			340,850	$13,975			$14,254
1903	437	3.58	$74	654	353			287,482	12,074			12,501
1904	385			741	424			310,409	13,580			14,004
1905	2,000			6,000	3,624			1,400,000	65,800			69,424
1906	7,113	2.75	57	5,777	3,871			956,060	54,495	2,176,200	$132,748	191,171
1907	10,765			2,534	1,673			953,759	50,549	4,154,988	245,144	297,366
1908	1,138			2,336	1,238			663,708	27,876			29,114
1909	4,028			994	517			389,427	16,745	1,817,542	98,147	115,409
1910	6,347	.21	4	969	523			549,069	24,159	2,843,032	153,524	178,210
1911	9,020	1.13	23	2,909	1,542	182	$23	2,313,093	104,089	4,118,414	234,750	340,427
1912	4,979			7,170	4,410			1,769,623	79,633	860,222	59,355	143,398
1913	918			407	246			125,875	5,538	416,922	23,348	29,132
1914	212			218	121			76,293	2,975	19,730	1,006	4,102
1915 [a]												
1916	4,051			410	270			179,686	12,398	1,730,645	231,906	244,574
1917	4,738			4,894	4,033			1,091,346	93,856	654,601	66,769	164,658
	56,483	7.67	158	36,539	23,124	182	23	11,406,680	577,742	18,792,296	1,246,697	1,847,744

[a] None.

ORE DEPOSITS.

WESTERN RANGE.

Ore deposits in the western range have been successfully worked at two places, the Scranton mines in Barlow Canyon, about 9 miles northwest of Eureka, and the New Bullion (Bal Hinch) mine in Miners Canyon, about 3 miles farther south. The ore bodies of the Scranton are in coarse-grained limestone of probable upper Mississippian age, identical in character with that of the Colorado Channel or north half of the Iron Blossom zone in the Tintic district. Those of the New Bullion are at a somewhat lower horizon, probably near the boundary between the Pine Canyon limestone and the underlying Gardner dolomite, but the stratigraphy in this vicinity has not been determined with certainty.

These ore bodies, which have yielded oxidized lead, lead-zinc, and zinc ores, are all formed along the intersection of single fissures or branching and crossing fissures with specially replaceable limestone beds. Most of them vary from small bunches to bedded replacement or blanket bodies of considerable extent. Those of the Scranton mines lie in a nearly north-south zone, strongly indicating that the mineralizing solutions migrated along a pronounced fissure zone and spread more or less where intersecting fissures or permeable beds gave opportunity. Fractures in that zone show premineral displacements of a few feet.

The ore and gangue are generally similar in character to those formed in the Tintic district by the cooler parts of the mineralizing solutions. The principal gangue along the trunk fissures is mostly dark cherty quartz, and away from the trunk fissures dolomite and calcite. Only small remnants of sulphide ore remain in the oxidized ore, which consists chiefly of cerusite, smithsonite, and calamine, and which contains galena and zinc blende but very little pyrite. The abundance of iron oxide in the ore, however, shows either that considerable pyrite was present or that the blende contained considerable iron.

The metal content of the oxidized ore depends largely on the thoroughness of replacement of the limestone by primary sulphides and on the amount of zinc that migrated during oxidation. Where replacement was complete the zinc was mostly removed from the lead ore during oxidation and was more or less concentrated into separate bodies or bunches. This process was especially pronounced in the southern part of the Scranton property, especially in the Magazine tunnel, where a large body of oxidized zinc ore was mined at the down dip end of a large lead stope. Where the primary ore only impregnated the limestone and did not wholly replace it the unreplaced part precipitated the oxidized zinc as carbonate and produced the lead-zinc or "combination" ore prominent in the northern part of the Scranton property and in part at least of the New Bullion mine.

The lead ores shipped have assayed 0.5 to 3 ounces of silver to the ton, 21 to 33 per cent lead, 2 to 3 per cent zinc, 22 to 32 per cent iron, and 8 to 24 per cent insoluble; the zinc ores 0.5 ounce of silver to the ton, 0 to 2.5 per cent lead, 32 to 52 per cent zinc, 6 per cent or less iron, and 14 per cent or less insoluble; the combination ores 0.5 to 7 ounces of silver, 8 to 40 per cent lead, 14 to 33 per cent zinc, 5 to 14 per cent iron, and 7 to 15 per cent insoluble. The low silver content, averaging about 1 ounce to the ton in the Scranton mines and about 5 ounces in the New Bullion mine, is characteristic.

Other properties, prospecting in mineralized ground of the same type as that described, are the North Scranton and the Tintic Zinc Co., which is located between the Scranton and New Bullion mines.

MIDDLE RANGE.

Little or no ore has been produced from the middle range, but several promising outcrops both of siliceous and nonsiliceous ore have been prospected to some extent. The siliceous outcrops are prominent at the south end of the range, north of Packard Peak, and are approximately in line with the Gemini ore zone of the Tintic district. They consist of gray cherty quartz replacing coarse-grained Mississippian limestone of the "Colorado Channel" type. The principal prospects from which any data have been obtained are the Farragut and De Prezin. Assays of material in the quartz replacement have shown low values in gold, silver, and copper, and up to 11 per cent lead. One small shoot said to assay 7 per cent bismuth was found in the De Prezin property.

Nonsiliceous ores are on the east slope of the range, about 7 miles north of Packard Peak,

on the Tintic-Humboldt property. The character of the ore and gangue minerals, so far as exposed, and the country rock, are the same as at the Scranton mines in the western range. Other mineralized outcrops of more or less promise have been prospected, but so far as known no ore of shipping grade has been found in quantity.

EASTERN RANGE.

The only ore body in the eastern range from which ore has apparently been shipped is one formerly worked in the Lehi-Tintic mine. The ore, an oxidized silver-lead of good grade, is said to have followed a N. 50° E. fissure, probably in Mississippian limestone, but to have pinched out downward. Later work has consisted of prospect tunneling beneath this body.

CANYON RANGE.[1]

By G. F. Loughlin.

GENERAL FEATURES.

The Canyon Range is in west-central Utah, in line with the East Tintic and Oquirrh ranges to the north. The few small mines and prospects in the range are scattered along the west slope from Leamington north for 12 to 13 miles to the hills south of Oak Creek (fig. 43), in the Leamington or Oak Creek mining district. Leamington, on the Los Angeles & Salt Lake Railroad, and Oak Creek, reached by a 10-mile stage route from Leamington, are small agricultural towns.

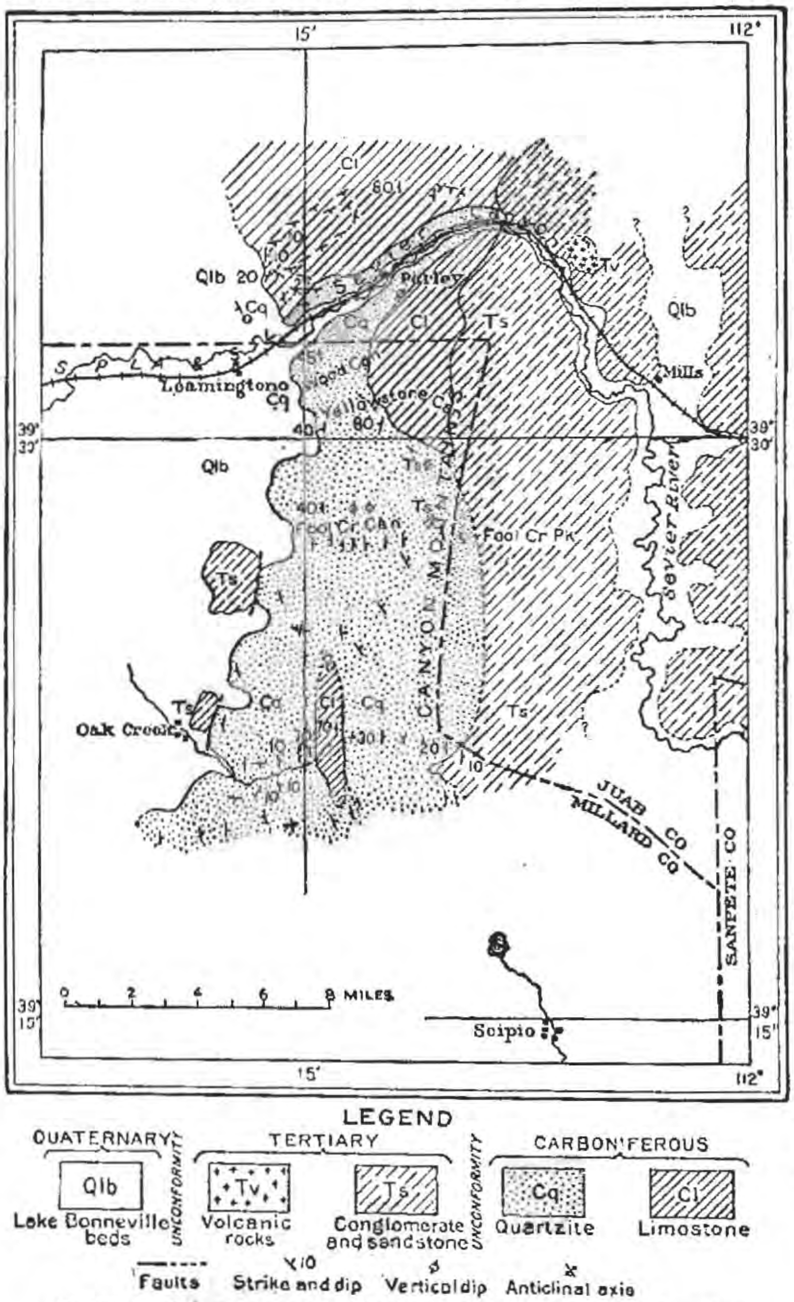

FIGURE 43.—Reconnaissance map of the Canyon Range showing geologic formations.

GEOLOGY.

The Canyon Range is composed almost entirely of sedimentary rocks—Carboniferous limestone and quartzite overlain unconformably by Eocene conglomerate, but volcanic rocks have been reported from the extreme northern and southwestern parts. The valleys on either side of the range are floored with the Pleistocene Lake Bonneville beds and locally with later alluvial deposits.

SEDIMENTARY ROCKS.

CARBONIFEROUS LIMESTONE.

The Carboniferous limestone is the prevailing rock northwest of Sevier Canyon and along the middle western slope of the range south of Sevier Canyon as far as the south boundary of

[1] For a less condensed description of the geology of this range see Loughlin, G. F., A reconnaissance in the Canyon Range, west-central Utah: U. S. Geol. Survey Prof. Paper 90, pp. 51-60, 1914. The origin of the range from the physiographer's standpoint is discussed by W. M. Davis (The Wasatch, Canyon, and House ranges: Harvard Coll. Mus. Comp. Zool. Bull., vol. 49 pp. 28-34, 1905).

Yellowstone Canyon. North of Sevier Canyon it has generally low dips, associated with gentle anticlinal and synclinal flexures, but locally its beds stand nearly vertical. South of Sevier Canyon its dip ranges from steep westerly to vertical. The limestone on both sides of Sevier Canyon dips beneath quartzite. A smaller limestone area lies across Oak Creek in a monocline, which dips 70° beneath the quartzite on the west and is separated from the quartzite on the east by a strike fault. Limestone is also said to be exposed in the narrow southern part of the range, near Scipio. A lens of limestone in quartzite was noted on the north side of Fool Creek, well above the main limestone formation.

The lithologic character of the limestone varies somewhat in different places. The lowest strata seen, about 3 miles northwest of Sevier Canyon, are thick to rather thin bedded, of medium to dark gray color, and fine to rather coarse grained texture. Fossils are fairly abundant in certain beds. At a higher horizon, due north of Parley station, which is 5 miles northeast of Leamington, intercalated beds of shale are conspicuous. About a mile north of Parley station, on the east wall of a southward-sloping canyon, a prominent bluff of vertical limestone and chert pebble conglomerate lies in the zone of these intercalated shale beds. The stratigraphic significance of this conglomerate can not be determined without detailed study, but from the paleontologic evidence it appears to be a local variation within a single limestone formation.

The uppermost limestone beds differ in character. On the west slope of the range, northwest of Sevier Canyon, they are very cherty, nodules and continuous bands of chert comprising as much as 50 per cent of them. Perfect pseudomorphs of brachiopod shells are conspicuous in much of the chert. Shale beds at this place are not conspicuous.

In Wood Canyon the uppermost beds are of light to medium gray color and are dolomitic. Many of them are characterized by a concretionary or pisolitic structure, the concretions ranging up to an inch or more in diameter and offering greater resistance to weathering than the matrix. Above and intercalated with these strata are beds of striped shaly limestone, alternating with shale, and these in turn are overlain by a bed of brown ferruginous quartzite, which is overlain by typical quartzite.

At no place is the entire thickness of the limestone exposed. A rough estimate of the exposed thickness northwest of Sevier Canyon gives 1,700 to 2,000 feet, but the many local variations in strike and dip give many chances for error. The thickness of the limestone in Yellowstone Canyon is certainly much greater, but the entire exposed width was not studied, and the lower part of the limestone is concealed beneath thick bodies of Eocene conglomerate. In Oak Creek canyon the exposed thickness is at least 3,500 and may be over 4,000 feet.

Fossils collected from the upper cherty limestone beds on the west slope of the range, 2½ to 3 miles northeast of Leamington station, were determined by G. H. Girty, of the United States Geological Survey, as follows:

Crinoid stems, large and numerous.
Zaphrentis sp.
Schuchertella chemungensis?
Schizophoria swallowi?
Spirifer centronatus.
Spirifer incertus?
Syringothyris carteri.
Cliothyridina aff. C. sublamellosa.

Another lot, collected at a horizon much lower stratigraphically, in the saddle between the two main ridges of the range, about 2½ miles north of Parley station, contains *Spirifer centronatus* and *Composita humilis*. Mr. Girty states that the first lot "is clearly of lower Mississippian or Madison facies," and that the second lot "is less diagnostic, since there are two Pennsylvanian species very similar to the only two comprised in the collection; but since the latter occurs below the first it must needs be Madison also." Fragments of fossils similar to those listed above were noted in Yellowstone Canyon in the upper part of the limestone.

The fossils prove that the upper 1,700 to 2,000 feet of the limestone is of lower Mississippian or Madison age. Cambrian fossils were found by Burling in the limestone area near Scipio,[1] and it may be that some of the limestone represents ages between Cambrian and Carboniferous, as in the Tintic district to the north.

[1] Burling, L. D., written communication.

QUARTZITE.

The quartzite of the Canyon Range is exposed along the western half of Sevier Canyon and extends continuously southward well beyond Oak Creek. South of the divide between the Yellowstone and Fool Creek canyons the quartzite constitutes the summit and entire western slope of the range, with the exception of the faulted band of limestone across Oak Creek.

The quartzite as a rule is of fine even grain and is nearly white to light and dark brown or reddish brown. Some of its beds are greenish. Its general appearance is very similar to that of the thick Cambrian quartzite exposed in the Tintic district and at several places along the Wasatch Range, thus accounting for the fact that the quartzite has heretofore been regarded as Cambrian.

The quartzite contains a conspicuous and persistent dark-reddish finely banded member, 400 or 500 feet thick, which is a convenient horizon marker and indicator of the geologic structure. (See figs. 44 and 45.) The northernmost exposure of this member is on the south side of Sevier Canyon, near its mouth, where it stands vertical in a pinched synclinal trough of southwesterly pitch. It was not traced southward across Wood and Yellowstone canyons but is undoubtedly present in that part of the range. South of Yellowstone Canyon the red member follows the west edge of the range almost as far south as Fool Creek. It then swings southeast, crossing the lower part of Fool Creek canyon and following an undulating course, probably passing north and east of Fool Creek Peak, the highest peak of the range. (See fig. 44.) South of Fool Creek canyon the red member is probably present in the western part of the range but was seen only in the vicinity of Oak Creek. North of Oak Creek canyon (see fig. 45) it is again prominent along the west edge of the range and is exposed in a very gentle anticline for a considerable distance along both walls of the canyon from near its mouth to the first north branch. Here a sudden steepening of the easterly dip carries it below the surface, but it reappears about a mile farther up the canyon a short distance west of the limestone band. It again appears

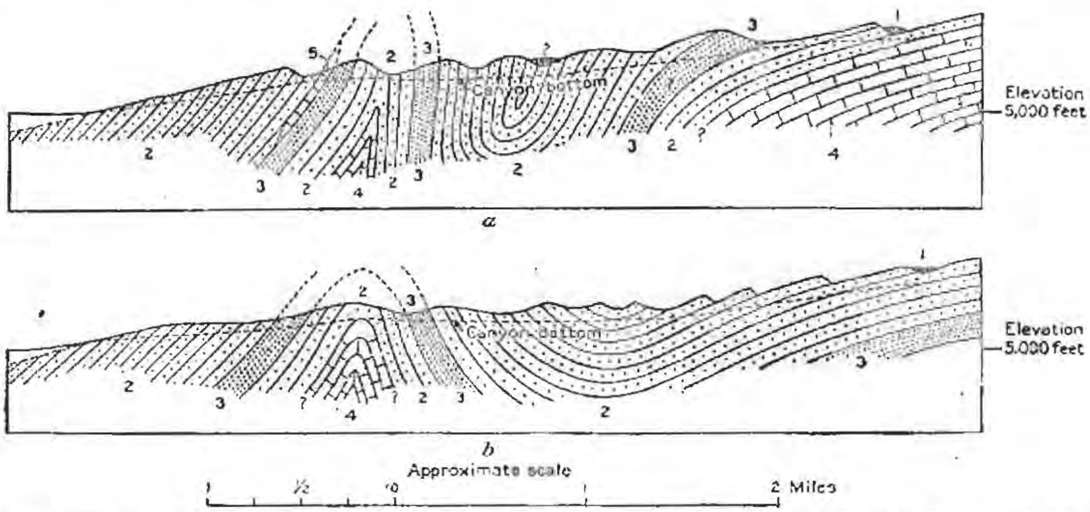

FIGURE 44.—Generalized section along north (a) and south (b) sides of Fool Creek canyon. 1, Tertiary conglomerate and sandstone; 2, Carboniferous quartzite; 3, red member of the quartzite; 4, Carboniferous limestone; 5, limestone lentil in quartzite.

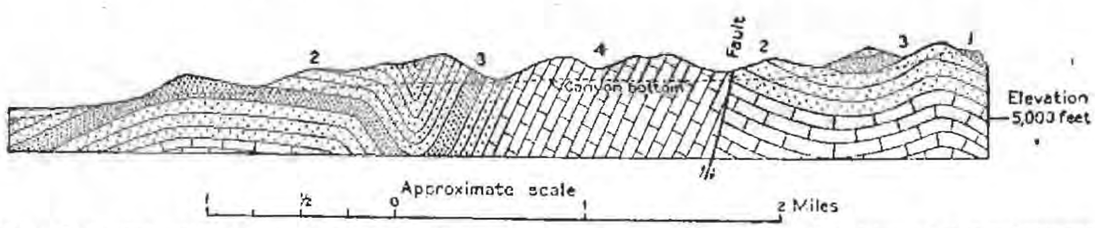

FIGURE 45.—Generalized section along north side of Oak Creek canyon. 1, Tertiary conglomerate and sandstone; 2, Carboniferous quartzite; 3, red member of the quartzite; 4, Carboniferous limestone.

in the trough of a gentle syncline on the north slope of the canyon near its head. It was not followed south of Oak Creek canyon.

A lens of gray limestone was noted on the north side of Fool Creek canyon, and detailed study may prove the presence of others.

The entire thickness of the quartzite was at no place exposed, owing to erosion of its upper portion. On the north side of Fool Creek canyon the thickness of the exposed vertical strata of the east limb of the close anticline appears to be at least 5,000 feet. Elsewhere the variations in dip prevented a closer estimate.

No fossils were found in the quartzite, but its apparent conformable position above limestone of Madison age suggests that its lower part at least is Mississippian, though its upper part may be Pennsylvanian. A similar quartzite of great thickness, containing some limestone beds, forms the greater part of the West Tintic Mountains, the southern end of which is almost connected with the northwest end of the canyon Range; and the writer has found upper Mississippian fossils in the limestone beds. Correlation, therefore, with this quartzite fixes the age of the quartzite of the Canyon Range as upper Mississippian.

EOCENE CONGLOMERATE.

The Eocene conglomerate is almost wholly confined to the east half of the range A few small outliers were noted on the higher spurs north of Fool Creek, and their approximate positions are shown in figures 44 and 45. A considerable area, in which the rocks are very poorly exposed, was traversed along the low foothills north of the town of Oak Creek.

In the principal area the Eocene consists of light-gray and red beds of conglomerate and sandstone, the conglomerate pebbles including limestone, quartzite, and chert. The western boundary of the principal area is exposed in Sevier Canyon near its northernmost point, where a coarse conglomerate rests unconformably on quartzite. On both sides of the canyon the boundary can easily be seen from a distance, owing to the marked contrast in color between the younger and older formations. South of the canyon the Eocene beds rest on the upturned lower Mississippian limestone and form the crest and upper west slope of the range along the heads of Wood and Yellowstone canyons. North of Fool Creek Peak the west boundary crosses the summit and extends southward along the eastern slope as far as the saddle at the head of Oak Creek canyon, where the contact is well exposed, the Eocene beds, with a dip of about 10° E., abutting against a steep erosion surface of quartzite.

The rocks which form the low foothills north of Oak Creek are almost completely reduced to a loose mass of limestone, quartzite, and chert cobbles, with a few remnants of consolidated conglomerate. The presence of the Eocene material in these deposits is presumably due to the sinking of a block during the faulting period when the Basin Ranges were developed.[1]

As only the eroded western edge of the Eocene beds was studied, no idea of its thickness was gained. The beds are assigned to the Eocene by correlation with similar strata in the southern Wasatch Mountains[2] and in the ranges immediately east of the Canyon Range.[3]

QUATERNARY DEPOSITS.

The Quaternary deposits include the Lake Bonneville beds of clay and marl deposited in Pleistocene time and the overlying alluvial deposits at the mouths of the canyons. The Lake Bonneville beds are terraced by Sevier River and are well exposed at Leamington and along the sides of Sevier Canyon.[4]

VOLCANIC ROCKS.

No volcanic rocks were seen at close range. From a distance a bed of dark columnar volcanic rock was seen overlying Eocene beds northeast of the canyon. (See fig. 44.) Volcanic rocks are said to be abundant in the extreme northern part of the range, and porphyry dikes are reported along Dry Canyon south of Oak Creek.[5]

STRUCTURE.

The Carboniferous rocks are characterized by a few major folds with steep dips, by several intervening minor folds with gentle dips, and by a prominent strike fault, which appears to be coincident with a broken anticline. The

[1] These foothills were tentatively regarded by Davis as abnormal landslides: Harvard Coll. Mus. Comp. Zool. Bull., vol. 49, geol. ser., vol. 8, No. 2, pp. 28–34, 1905.

[2] Loughlin, G. F., Jour. Geology, vol. 21, p. 448, 1913.

[3] U. S. Geog. Surveys W. 100th Mer., atlas sheet 50.

[4] Gilbert, G. K., Lake Bonneville: U. S. Geol. Survey Mon. 1, pp. 104, 166, 192, and 193, 1890.

[5] Oral information by James Overson, of Leamington, Utah.

northernmost major fold is the asymmetric syncline of southwesterly pitch, whose axial plane is nearly parallel with the western half of Sevier Canyon. Its northwest limb dips 25°–40° SE. and becomes lower away from the axis, passing into an area of prevailingly monoclinal structure, though the general low and regular inclination of the beds is interrupted by several inconspicuous anticlines and synclines. The southeast limb is nearly or quite vertical along Sevier Canyon, but along Wood and Yellowstone canyons it dips about 45° W.

In Fool Creek canyon an anticline and syncline with north-south axes are exposed. (See fig. 44.) On the north side the details of the structure are not very clear. The moderate westerly dip of the quartzite changes eastward to vertical, which persists for about 1½ miles and then gradually changes to a moderate westerly dip, which continues eastward probably to the crest of the range. The only clue to the structure is given by the red quartzite member, aided by comparison with the simpler structure on the south side of the canyon, which shows the strata to be folded into a close anticline of vertical dip and an unsymmetrical syncline with vertical west limb and moderately dipping east limb. (See fig. 44.) Detailed study, however, may show the vertical strata to be more complexly folded. The structure on the south side of the canyon needs no special comment. The lengths of these folds are not definitely known, but the anticline may extend as far north as the rim of the south fork of Yellowstone Canyon, where the uppermost limestone beds stand nearly vertical. That the limestone is probably not far below the surface where the anticline crosses Fool Creek may be inferred by the proximity of the red member of the quartzite to the top of the limestone in Sevier and Oak Creek canyons.

Between Fool Creek and Oak Creek canyons several minor folds can be seen from the western foothills. In the lower part of Oak Creek canyon a gentle anticline with limbs dipping about 10° is well exposed. About 2 miles above the mouth this passes into a syncline, both of whose limbs dip 60° to 70°. (See fig. 45.) The west limb is relatively small, but the east limb is at least 1½ miles in horizontal width and brings the limestone to the surface. The limestone is bounded on the east by a strike fault, probably a compression fault, which separates it from quartzite of gentle easterly dip. East of the fault the quartzite is folded into a rather gentle syncline and anticline, the anticlinal axis lying just east of the crest of the range.

The character of the folds shows that the dominant compressive force was eastward in the central and southern parts of the range and northwestward in the northern part.

LEAMINGTON (OAK CREEK) DISTRICT.

ORE DEPOSITS.

CHARACTER AND DISTRIBUTION.

The Leamington or Oak Creek district, which extends along the west slope of the range, was organized March 11, 1886. During 1895, when the second smelter was operated for the treatment of ores of the Ibex and Charmed mines produced in the Detroit district, some of the lead ores from the Leamington district are said to have been utilized, but no record of the amount is available. The White Horse claim in 1901 yielded 7 tons of silver ore, presumably containing lead, but no record of the lead was kept. The Yellowstone claim from 1903 to 1906, inclusive, shipped to the Salt Lake smelters 350 tons of lead ore carrying silver.

LEAD AND ZINC.

Yellowstone mine.—The Yellowstone mine is in the south fork of Yellowstone Canyon, about 4 miles southeast of Leamington. The workings include an inclined shaft 200 feet deep, following the dip of the limestone (about 60° W.), and drifts at the 50, 100, and 170 foot levels. The ore forms small replacement bodies in one of the limestone beds adjacent to fissures. On the 50-foot level small bodies were stoped along a north-south strike fissure and one body where the bed was somewhat shattered at the intersection of the strike fissure and an east-west cross fissure. The 170-foot level follows the contact between a shale and limestone bed, along which a zone of veinlets, consisting chiefly of spar (dolomite and calcite), is said to assay 3 to 4 per cent lead.

The ore stoped consisted principally of galena and cerusite (lead carbonate) in a gangue of ferruginous dolomite and calcite spar. A little secondary aragonite was noted on a crust of fibrous calcite that lined a pocket along the strike fissure on the 50-foot level. Assays of the ore have run from 30 to 65 per

cent lead, the higher grade carrying 5 to 6 ounces of silver. A little gold has also been reported. The mine has been worked intermittently and has shipped only about 15 carloads of ore in more than 20 years. No zinc has been found.

Arbroath mine.—The Arbroath shaft is about an eighth of a mile north of the Yellowstone, in a low spur which separates the south fork from the north fork of Yellowstone Canyon. The material on the dump shows the mineralization to be of the same type as that of the Yellowstone mine. The ore found during assessment work is reported to be of two grades, the higher carrying 76 per cent lead and 9 ounces of silver and the lower 10 to 11 per cent lead and 1 ounce of silver. Only a small quantity of ore has been found thus far.

Wood Canyon group.—The Wood Canyon group of claims is on the north side of Wood Canyon and includes the uppermost beds of the limestone formation. The mineralized outcrop is a brown, rust-stained dolomitic bed, containing a large amount of ferruginous dolomite spar, white where fresh and brown where weathered, through which are scattered grains of galena and yellowish-brown zinc blende. The stained rock is closely associated with two fissures, one trending north and the other S. 55° E., both of whose outcrops are marked by shallow gulches.

COPPER PROSPECTS.

A small copper prospect in quartzite on the low ridge just north of the mouth of Fool Creek canyon consists of mineralized white vein quartz with numerous fractures stained by films of green and blue copper carbonates, and containing small spots and patches of dark-brown iron oxide evidently derived through oxidation of pyrite and chalcopyrite. Other copper and lead prospects have been reported along Dry Canyon, south of Oak Creek.

COMPARISON WITH ORES OF OTHER DISTRICTS.

The lead and lead-zinc ores of the Canyon Range are similar in mineralogy and mode of occurrence to certain ores in the North Tintic, East Tintic, Santaquin, and Mount Nebo districts. The ores of these districts are, as a rule, rather remote from important bodies of intrusive igneous rock and consist essentially of galena, zinc blende, and more or less pyrite, or oxidation products of these sulphides, in gangues of dolomite, calcite, and minor quartz. Their usual silver content averages 3 to 5 ounces, but in some deposits rises to 10 ounces per ton. The sizes and shapes of the ore bodies vary according to conditions; some strong fissures contain continuous veins, and some permeable beds of pure limestone are rather extensively replaced; but argillaceous and dolomitic beds have yielded only small bodies of high-grade ore and a few more extensive bodies of milling ore.

The ore bodies of the Canyon Range are no exception to this rule. Those mined have replaced dolomitic limestone beds along their intersections with narrow fissures and are small or of low grade. The higher-grade ore bodies may be mined at no great expense, but the cost of prospecting for new bodies after old ones have become exhausted is likely to equal or exceed the net receipts from ore sales.

Small copper prospects found near the lead and zinc mines in some of the districts named are quartz veins containing chalcopyrite and pyrite or their oxidation products and are confined to the siliceous rocks—quartzite, schist, or granite. The copper prospects of the Canyon Range may, from the meager knowledge available, be classed with this type. A few veins intermediate in composition between these and the lead and zinc deposits have been found, suggesting that the two types were derived from a common source. None of these copper-bearing veins appear to have yielded steady shipments of ore.

SHEEPROCK MOUNTAINS.

By G. F. Loughlin.

GENERAL FEATURES.

The Sheeprock Mountains (fig. 46) form a narrow range about 20 miles long that trends northwest across longitude 112° 30′ W. and latitude 40° N. They lie between the Simpson Mountains on the west and the West Tintic Mountains on the east, and form a southward continuation of the Onaqui Range, separated from it by a low pass west of Fausts. Mining districts in the range are the Columbia, the eastern part of the Erickson, the Blue Bells, and the West Tintic.

The highest summits of the range rise 7,000 feet and more above sea level. Both the east

and west slopes are pronounced, but the western are the steeper. Canyons cut both the west and east bases of the range well back toward the middle, leaving rather a narrow sinuous crest line. Those in and near the granite stock on the west slope (Pl. XII, *B*, p. 101) are distinctly "hanging" in character. They maintain broad V-shaped cross sections and uniform gently graded bottoms throughout most of their courses, but near their mouths grades, merging without breaks into the alluvial slopes which fringe the range.

Many of the canyons contain running water, and the bottoms of those in the northern half of the range are covered with a rather thick tree growth, in marked contrast to the semi-arid alluvial slopes and valleys into which they empty. Although the mountains are well watered, even the larger streams disappear very near their canyon mouths. These streams

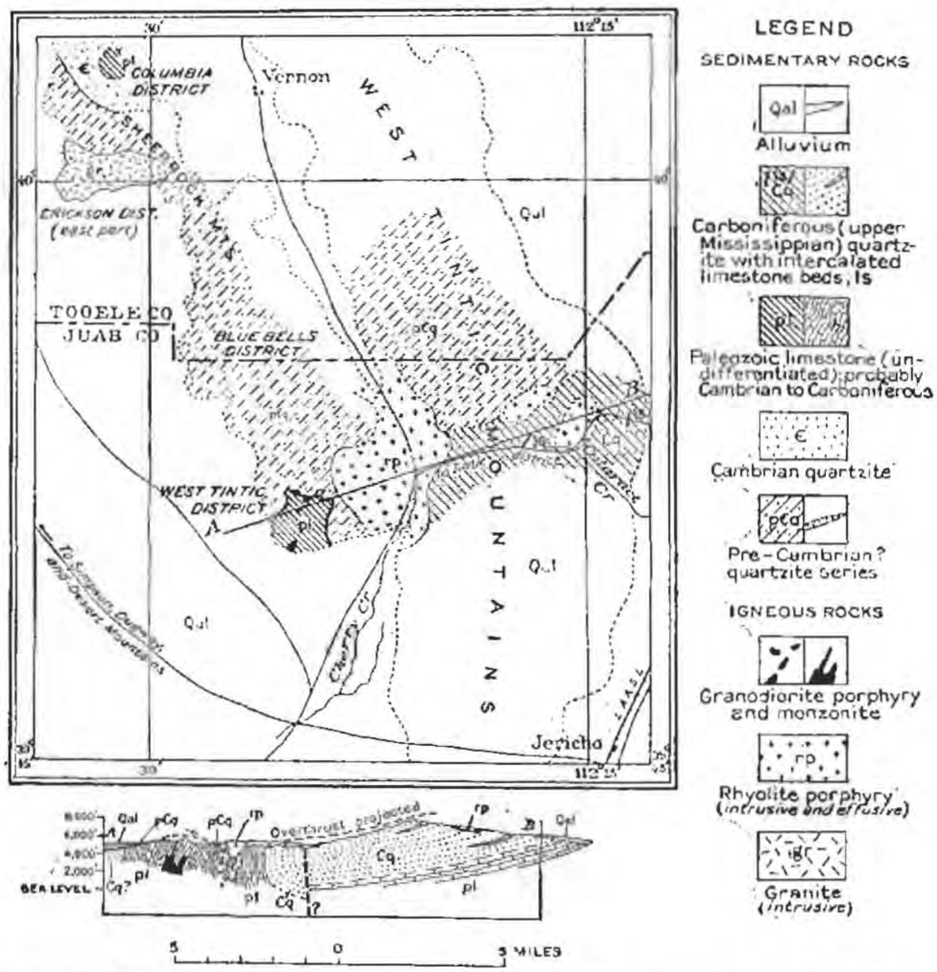

FIGURE 46.—Reconnaissance geologic map of the Sheeprock Mountains and part of the West Tintic Mountains.

the bottoms steepen abruptly and their creek beds follow a sharply zigzag course between low vertical walls. There are no indications of glaciation, and, as the base of the range is well above the highest level of Lake Bonneville, a lowering of water level can not account for the hanging character. Quite possibly it is due to a renewal of faulting and uplift in rather recent times, since which the small creeks have been able to make only a beginning of down cutting to the new base-level. The canyons in the east slope have normal irrigate a few ranches near the base of the range.

GEOLOGY.

The Sheeprock Mountains (see fig. 46) consist mostly of sedimentary rocks. The most extensive formation is a series of dark to light brownish quartzite, shale, and conglomerate, of probable pre-Cambrian age, that stretches from the south end of the range for three-fourths of its length. Overlying this in the northern part of the range is a succession of Cambrian quartzite, shale, and limestone. At

the southern end of the range, in the West Tintic district, an area of limestone of undetermined age probably includes Cambrian, Mississippian, and perhaps intermediate strata. This limestone is separated from the pre-Cambrian (?) quartzitic formation by an overthrust fault. All the formations dip prevailingly northeastward, and all dip at low angles, except those of the southern limestone area, most of which dip steeply.

Igneous rocks are represented by a prominent stock of granite or granodiorite in the north-central part of the range and by several small stocks of granitic, monzonitic, and rhyolitic rocks at the southern end. Dikes and sills of granite, granite or rhyolite porphyry, and monzonite or diorite porphyry are abundant in places and have been noted in the vicinity of all mineralized areas.

COLUMBIA AND ERICKSON DISTRICTS.

The Columbia district and the eastern part of the Erickson district (the western part is in the Simpson Mountains) lie in the same mineralized area in the north-central part of the range. The Columbia district lies east and the Erickson district west of the divide. The geologic formations include pre-Cambrian (?) and Cambrian sedimentary rocks, the largest granite stock of the range, and dikes of rhyolite and monzonite porphyry.

GEOLOGY.

SEDIMENTARY ROCKS.

The sedimentary rocks overlie the intrusive granite, striking from northwest to west and dipping northeast of north. Near the intrusive contact this dip is rather steep, averaging about 45° N. or NE., but it appears to flatten as distance from the contact increases.

The pre-Cambrian (?) includes beds of pure and of dark chloritic quartzite, chloritic shale, and poorly assorted conglomerate. A section through the upper parts of Hard-to-Beat Canyon on the southwest and of Harker Canyon on the northeast of the divide shows in ascending order, first, a zone of prevailingly light-colored quartzite just above the intrusive granite contact; second, a series of chloritic conglomerate, quartz, and shale; third, a zone of prevailingly light-colored quartzite; and fourth, a zone of green, purple, and black shale. Each zone, however, contains beds characteristic of the other three. The fourth zone is overlain by light to dark gray limestone of Cambrian age.

The light quartzite is typical and requires no special description. Contact metamorphism has made no conspicuous change in its character.

The chloritic series, where unaltered, is green on fresh and dark brown on weathered surfaces. The pebbles of the conglomerate consist of vein quartz, granite, gneiss, and quartzite, in a sandy matrix of chlorite, sericite, and fine quartz and feldspar grains. The quartzitic and arkose layers are of the same composition as the conglomerate matrix. The shale differs from the quartzitic beds in a predominance of chlorite and sericite over quartz and feldspar. The appearance, however, of the chloritic rocks along the upper slopes and summits visited is much changed by contact metamorphism. They appear crystalline, and at a glance may readily be mistaken for greenstones—chloritized dolerite or diabase. This is especially true of the more arkose beds, but the conglomerate is readily identified by its pebbles, which are embedded in a crystalline matrix but have undergone no conspicuous change themselves.

The shale beds have lost much of their shaly character, and the terms hornfels and slate are appropriate to some of them. Much of the shale along its bedding planes has developed small "knots" or lumps common to many contact-metamorphosed slates. No careful study of this metamorphism was made, but there seems to have been little or no change other than the recrystallization of the minerals in the rock with consequent obliteration of clastic structure. The "knots" in the only specimen collected proved in thin section to be wholly changed to limonite.

The limestone was not studied, as no ore deposits in it have yet been reported. Fossils said to have been found in its basal beds east of James's ranch near the north end of the west face of the range indicate Middle Cambrian age. L. D. Burling, who identified the fossils, reports as follows:

> This locality, for which little stratigraphic information was obtained in the field, can be definitely correlated with a section which I measured in 1905 in the Simpson Mountains, where it forms the third limestone bed above the quartzite series. It is Middle Cambrian in age and is probably to be correlated with the Wheeler formation in the House Range. It contains *Ptychoparia kingi?* and *Agnostus interstrictus?*

IGNEOUS ROCKS.

The granite forms the south and southwest precipitous fronts of the range and extends well up the canyons to within a mile of the divide. Its upper contact slopes eastward and probably northward, eventually disappearing beneath the surface. The low flat ridges at the south base of the range are also of disintegrated granite which passes insensibly into the alluvial slopes of the valley. The granite is of the same general character as that of Desert Mountain. Its outcrops are in general badly crumbled to a depth of a foot or more, and it is thoroughly cut up by vertical and inclined sheet jointing, which has permitted successive thin sheets to be removed by erosion, thus maintaining nearly vertical cliff faces of considerable height. The main type is light gray in color and medium to coarse grained porphyritic in texture. Most of the phenocrysts are white to pale-pink alkalic feldspar 1 inch or less in length or are slightly weathered smoky quartz in round to irregular grains one-third of an inch or less in diameter. A few are flakes of biotite one-eighth of an inch and more in diameter. The groundmass doubtless contains both plagioclase and alkalic feldspar with quartz, biotite, and minor accessories, but all that was seen was too badly weathered to permit megascopic distinction between the groundmass feldspars and too crumbly to be studied in thin section. The main type is cut by many local dikes ranging from aplite to pegmatite in texture, many of them having margins of aplite and middle portions of pegmatite or even pure quartz. Most of the dikes seen trend about N. 25° W. Near the contact with the overlying quartzite the granite is finer grained but maintains the porphyritic character. This contact phase, exposed along the upper walls of canyons, is cut by parallel joints dipping about 40° W. and so closely and evenly spaced that the rock resembles a sedimentary formation when viewed from the canyon bottoms.

Two dikes of rhyolite, or quartz porphyry, were found on J. H. Ekker's Godiva claim in the reentrant at the south base of the main granite body. They trend a little north of west and dip 60° S. or more, cutting through a complex of granite and metamorphosed arkose (which resembles fine dark granite). They are light gray to pale pink, with dense groundmass and small typical phenocrysts of feldspar and quartz. One weathered dike of rather acidic monzonite porphyry cuts the metamorphic chloritic sediments in a saddle on the crest of the ridge above the Sharp mine.

FISSURES.

The principal joint systems, including much vertical sheet jointing, strike N. 25°–45° W. and approximately northeast around the Copper Jack mines at the south base of the mountains. A mile or more to the west, at the mouth of Hard-to-Beat Canyon, they strike north and east, northwest, and northeast, and minor joints lie in various intermediate directions. Farther north, around the Old Sharp mine, they strike prevailingly north and east. In all these places the northwest and north joints dip southwest or west, the northwest generally between 65° and 45° and the north about 80°. The northeast and east joints, so far as seen, are mostly vertical, but some northeast ones dip steeply southeast. The joint systems show no direct relation to the dikes, but some of them evidently served as channels for ore-forming solutions.

HISTORY AND PRODUCTION.

By V. C. Heikes.

The Erickson (Black Crook) district was organized January 30, 1894. No production from it has been recorded by the United States Geological Survey.

The Columbia district, in Tooele County, 9 miles southwest of Vernon, was organized the later part of 1871. According to Huntley[1] there was some excitement there in 1871 and 1872 and again in 1875 and 1876. In 1875 the Ohio Co. spent a large amount of money recklessly and failed. The veins worked averaged 3 to 4 feet in width, but the ore, which is said to have averaged 10 to 25 ounces of silver and 30 to 40 per cent lead was of too low grade to pay at that distance from a market. Several hundred tons were shipped, but developments were, as a rule, very slight. In 1880 only about 10 claims had kept up assessment work.

Since 1880 the Sharp mine, a lead-silver-zinc property, has been the only notable producer. In the later part of 1908 a 50-ton

[1] Precious metals: Tenth Census U. S., vol. 13, p. 455, 1885.

concentrator, equipped with rolls, Huntington screen jigs, and Wilfley tables, was built. Some lead concentrate was shipped in 1908 and 1909, and shipments of lead-zinc sulphides have been reported.[1] In 1914 the lessees were shipping a fair grade of crude ore.

ORE DEPOSITS.

OCCURRENCE AND CHARACTER.

The ore deposits are veins in granite or in quartzite, none in limestone having been reported. They may be classified as quartz-feldspar veins carrying specularite and galena, quartz-fluorite veins carrying pyrite and chalcopyrite (copper veins), and quartz veins carrying pyrite, zinc blende, and galena (lead-zinc veins). Only the last two are of economic interest. The copper deposits lie along the south base of the granite stock and the lead-zinc deposits to the north in the quartzite and shale on the upper slopes; but it is quite possible that some copper ore also occurs farther north.

QUARTZ-FELDSPAR VEINS.

The one quartz-feldspar vein found is on J. H. Ekker's Godiva claim. A shattered zone trending east to east-southeast through metamorphic arkose and granite is filled by a network of small irregular veins which are accompanied by some impregnation and replacement of the walls. Talus greatly obscures the outcrops, and good exposures are seen only in a few shallow prospect pits and two short tunnels. The vein matter varies from fine pegmatite to nearly pure quartz, quartz forming the margins and feldspar as a rule filling the central portions. From its optical properties the feldspar appears to be mostly orthoclase, but it includes a few grains of plagioclase. The kaolinized state of the feldspar renders the determinations rather unsatisfactory. A little microscopic muscovite is present in the veins. Both the pegmatitic and the quartzose portions contain specularite and more or less galena. The specularite is very similar to the galena in color and luster and may easily be mistaken for it at a hasty glance but can be readily identified on close inspection by its flaky or scaly form and its red streak. A few microscopic pyrite grains are associated with the specularite.

The wall rock, whether arkose or granite, is altered to an aggregate of quartz and sericite which in places is impregnated with considerable specularite. Galena seems on the whole to be limited to the veins. The total width of the veined and impregnated zone in some exposures is 10 to 15 feet. A small and exceptionally rich sample from a shallow pit in veined and completely silicified granite is said to have assayed 6 per cent lead and 15 ounces of silver per ton.

This vein zone is closely related to the local aplite and pegmatite dikes in character. Some phases of the granite contain large blebs of quartz identical in character with those in small pegmatite segregations which contain a little specularite and possibly once contained a little pyrite or galena now represented by small rusted pits. The pegmatite phase in turn appears to grade into the quartz-feldspar veinlets, which contain well-crystallized quartz of earlier growth than the feldspar, and which are accompanied by alteration and impregnation of the wall rock. Further data as to the relative age of the veins could not be obtained A rhyolite ("quartz porphyry") dike, distinctly later than the aplite and normal pegmatite, forms the approximate hanging wall of the vein zone for a short distance, but the exposures are so poor that it could not be determined whether the vein is later than the dike or whether the dike is later than the vein and coinciding with its course merely by chance. If the dike is later than the vein there may be two periods of mineralization; for although the quartz-fluorite veins (next described) do not come in contact with rhyolite dikes in this vicinity they do elsewhere and are everywhere later than the dikes.

COPPER VEINS.

The quartz-fluorite veins with pyrite and chalcopyrite lie west of the Godiva claim, near the base of the granite cliffs. Four properties on these veins have been worked, but all were idle and their workings were inaccessible when visited. Apparently the veins follow the N. 25°–45° W. fissures. Two of them evidently form sheeted zones in porphyritic granite, and the filling of closely parallel fissures was accompanied by alteration and replacement of the intervening granite. The veins are said to range from a mere streak to 6 and to even 15

[1] Communication from L. D. Gordon to G. F. Loughlin.

feet. Nothing definite can be said regarding the horizontal extent of the veins or of the proportion of rich ground in the whole vein. The vein minerals vary in quantity, and all of them are not present in all specimens. The general arrangement, judging from specimens on the dumps, is for fluorite and the sulphides to segregate near the margins of fissures and for quartz to fill the central portions, but this arrangement evidently depends on the degree to which the different minerals have been able to segregate. In specimens showing the margins of veins the granite retains its appearance, but the original biotite is replaced by small pyrite grains, and the plagioclase by a soft yellowish-green material (presumably a microscopic aggregate of sericite and silica possibly stained in places by green copper minerals); the alkalic feldspar and quartz have undergone no appreciable change. The vein contact is sharp but not straight, suggesting that a portion of the wall has been replaced. The fluorite forms single crystals and coarse-grained aggregates of colorless to purple (green where stained with malachite), either pure or mixed with the other minerals. The pyrite and chalcopyrite also tend to form separate aggregates, and some specimens are composed almost wholly of chalcopyrite and fluorite in irregular masses, but others are composed chiefly of fluorite and pyrite. Quartz forms a matrix for the other primary vein minerals and also forms small prisms of late primary or secondary origin along minor fractures. Study of polished surfaces and thin sections shows that the pyrite and fluorite finished crystallizing about the same time and earlier than the other minerals. Some of the pyrite crystals were distinctly earlier than the fluorite. The chalcopyrite and quartz crystallized together, but the quartz continued to crystallize after the chalcopyrite had all deposited. This order, pyrite, fluorite, chalcopyrite, quartz shows the order in which the minerals finished crystallizing, but the periods of crystallization clearly overlapped, and some quartz was crystallizing before all the pyrite. A few microscopic scales of specularite were found inclosed in quartz, but its relations to the other minerals could not be determined.

Superficial alteration in the veins is marked by partial alteration of pyrite and chalcopyrite to limonite, and by the filling of fluorite cleavage cracks and small fractures in both veins and walls with malachite and iron oxide. Small vugs may be partly filled with white to pale-brown kaolin, evidently introduced mechanically by infiltrating waters. The incompleteness of oxidation and the shallow depth to ground water are not favorable to the occurrence of any strong zones of enriched sulphides, and it is probable that the value of the ore as a whole will not improve with depth. The copper content of the ore on the dumps does not average much if any over 5 per cent and nothing indicates a high tenor in silver.

The principal workings in this type of vein are those of the Copper Jack Mining Co., which has operated the Copper Jack and Flying Dutchman shafts. According to C. C. Griggs, president of the company, the Copper Jack shaft is 140 feet deep and follows a 3-foot vein which averages 6 per cent copper. The Flying Dutchman claims have two inclined shafts, one of which is about 240 feet long with a slope of about 40° and follows a vein considerably richer in copper than the Copper Jack. Its width is 3 to 15 feet. The Copper Jack shaft struck a strong flow of water at about 80 feet, and water was standing within 20 feet of the surface when seen by the writer. The water surface in the Flying Dutchman shaft is said to stand about 100 feet down the incline. Four veins are said to run lengthwise (average trend, N. 30° W.) through the property. Their average copper content is 3 to 5 per cent, but one 100-foot portion of the Copper Jack vein carries 7 or 8 per cent and includes considerable high-grade material running 20 to 30 per cent. The silver ranges from 1 to 7 ounces per ton.

The other properties in the vicinity are those of the White Rat (formerly the New Utah) Mining Co. and the Right Bower Mining Co. Their ore and gangue are of the same type as that of the Copper Jack. Both have struck water at shallow depths, the water in the Right Bower shaft standing close to the surface.

The great obstacles which prevent the successful mining of these veins is the shallow depth to water, which involves the necessity of pumping almost from the start of operations, and the 30-mile haul to the railroad at Tintic Junction or Center.

LEAD-ZINC VEINS.

OCCURRENCE AND CHARACTER.

The quartz veins with zinc and lead minerals are found on the upper slopes of the range on both sides of the divide and have been worked in Harkers, Albert Ekkers, Pine, and neighboring canyons. The mines and prospects here too were all idle when visited, and none of the workings was accessible, so that study was necessarily confined to the dumps. The ore fragments vary from pyrite with no other visible sulphides to irregular mixtures of pyrite, zinc blende, and galena. Quartz is the only gangue mineral seen in many specimens, but others, which represent replacement or impregnation of chloritic wall rock, contain considerable chlorite. A thin section of the chloritic rock suggests that impregnation of the ore minerals has been accomplished by recrystallization (and partial removal) of the wall rock, the quartz re-forming into relatively few and large crystals interspersed with felty masses of practically pure chlorite. The ore minerals as a whole have intergrown contacts with the gangue, but many of the pyrite crystals are nearly perfect, whereas the galena and blende as a rule have irregular outlines.

Oxidation is well advanced in the uppermost parts of the veins nearest the divide, and the removal of sulphides has left a limonite ore more or less filled with white cerusite (lead carbonate) crystals and presumably carrying considerable silver.

The only mines which have shipped ore from this type of vein in recent years are the Sharp and the New Sultana.

SHARP MINE.

The Sharp mine, at the head of Harker Canyon in the Columbia mining district, has, as already noted, produced lead concentrates, a small amount of lead carbonate ore, and some lead-zinc sulphide ore. According to L. D. Gordon, a former operator of the mine, the lead carbonate ore contained about 40 per cent lead and 20 ounces of silver to the ton, and the mixed sulphide ore about 30 per cent lead and 25 per cent zinc. The mine has been worked through tunnels aggregating 1,250 feet in length. The main tunnel when visited was caved in, and a small stream of water issued from it. The ore on the dump included both primary sulphide, lead carbonate, and limonite, but nothing is known of their relative amounts. The wall rock includes a large amount of the chloritic beds that have been replaced and impregnated to some extent by ore. The ore recently mined by lessees has been hauled by wagon to Dunbar, a station on the Los Angeles & Salt Lake Railroad, about 12 miles to the east.

NEW SULTANA MINE.

The New Sultana ore body had not been opened at the time of the writer's visit in 1912. It is reported [1] to be a vein 4 feet thick in quartzite, and the ore is said to contain 60 cents in gold and 5 ounces in silver to the ton, 48 per cent lead, and 28 per cent iron. The zinc content is not known. One hundred tons of ore are said to have been mined in 1914.

OTHER PROPERTIES.

Deposits on the Erickson side of the divide include the Indianapolis in Pine Canyon, the Free Coinage in Albert Ekkers Canyon, and others whose names have not been learned. No information regarding the extent of the veins or values of the ores on these properties has been obtained. Ore from these mines must be hauled 20 miles down canyon roads of generally gentle grade to the valley west of the mountains and northward and eastward along the valley road through the pass to Faust and Center. The mines on both sides of the divide are thus handicapped by distance from a railroad but are fortunate in their location on steep slopes where tunnels from the canyon bottoms can be driven and made to drain the portions of the ore bodies which lie above the canyon levels.

BLUE BELLS DISTRICT.

LOCATION.

The Blue Bells district lies on the east side of the Sheeprock Mountains, about 6 miles southeast of the Erickson district and close to the south boundary of Tooele County. It is reached by a 10-mile wagon road from Lofgreen, on the Los Angeles & Salt Lake Railroad. The road extends westward from Lofgreen, across a low pass in the West Tintic Range, and turns southward along

[1] Oral statements by Lew Merriman and James Morgan, of Eureka, Utah.

Vernon or Faust Creek to Green's ranch, where it turns westward again along a shallow canyon through the east foothills of the Sheeprock Mountains.

PRODUCTION.

By V. C. Heikes.

The Blue Bells district was organized on February 12, 1896. Its known production has been small.

Metals produced in Blue Bells district, 1891–1917.

Year.	Ore (short tons).	Gold.		Silver.		Lead.		Total value.
		Fine ounces.	Value.	Fine ounces.	Value.	Pounds.	Value.	
1891	37	1.30	$27	617	$611	46,686	$2,008	$2,646
1899	45	1.09	22	871	523	48,560	2,185	2,730
1900	27	....	....	487	302	32,256	1,419	1,721
1901	52	1.35	28	1,039	623	61,356	2,638	3,289
1902	43	.87	18	1,006	533	50,052	2,052	2,603
1904	21	.41	8	354	203	23,975	1,049	1,260
1915	12	.12	2	274	139	12,414	584	725
1917	12	....	....	297	245	9,258	796	1,041
	249	5.14	105	4,945	3,179	284,557	12,731	16,015

GEOLOGY.

The only sedimentary formation noted was the great series of early Cambrian or pre-Cambrian quartzite, shale, and conglomerate, which is so prominently exposed in the Erickson and Columbia districts to the northwest. The strata at and near the crest of the range, around the Morgan workings, strike northwest and dip 40° NE. A mile or more to the east, around the Black Hawk workings, they strike nearly east and dip north at a low angle. Not enough work has been done to determine the structure accurately, but the strata appear to form a monocline, broken by major and minor faults.

The quartzite members of the series are light to medium brown, medium grained, and in places cross-bedded. The shale is greenish gray where fresh and brown where weathered and has a more or less metamorphosed appearance, locally with the characters of slate or even phyllite. The conglomerate is typically unassorted and is composed of subangular pebbles of quartzite, metamorphosed shaly rock, granite, and gneiss in a matrix of shaly character. The pebbles, or cobbles, are prevailingly large, being 4 to 12 inches or more in diameter. The largest noted was an elliptical quartzite boulder 4½ feet long. The irregular size and distribution of the pebbles and the shaly character of the matrix suggest a glacial origin for the conglomerate.

The only igneous rock noted was a highly weathered northwestward-trending dike of monzonite porphyry, about 200 feet wide, exposed on a high short spur just northeast of the Morgan shaft. It lies between a southwest wall of quartzite and a northeast wall of shale, relations which suggest that it was intruded along a fault.

The principal structural feature, other than the moderate degree of folding already mentioned, is faulting. Faults of rather small displacement and fissures are numerous in the limited area examined, but not enough observations were made to determine the directions of the principal systems. The strongest faults and fissures noted trend N. 40° W. with dip 55° SW., N. 30° E. with dip 70°–80° SE., and N. 85° E. with dip about 50° S. One of the N. 40° W. faults is accompanied by accessory fissures, characterized by brecciation but little or no apparent displacement. These accessory fissures trend N. 60°–70° E., north, N. 20° E., and east. They were noted only at one place, the Black Hawk workings, where they appeared to radiate from a N. 40° W. fault.

ORE DEPOSITS.

MINES.

The only ore deposits reported in the Blue Bells district are those on the R. E. P. property, which includes two groups of workings, the Morgan and the Black Hawk.

Morgan mine.—The Morgan workings lie close to the crest of the range and include one inclined shaft and two tunnels. One vein has been worked through the shaft and upper tunnel, and another mineralized fissure has been prospected through the lower tunnel. The productive vein, where stoped, strikes N. 85° W. and dips 50°–55° S. West of the stoped ground the strike is said to curve southwestward. Below the stope the dip is said to flatten to 42°. Ore of shipping grade was found close to the surface and extended down the dip for 80 feet, to a short distance below the tunnel level, and then pinched out. The inclined shaft followed the ore; and the upper tunnel, 45 feet vertically below the shaft collar, was driven along the strike of the vein for 185 feet. The stoped ground had caved and could be studied only at its eastern end.

The ore seen consisted of brecciated quartz cemented by a mixture of galena and cerusite, accompanied by a little quartz and barite. Quartz in fine druses and a few barite crystals are the only conspicuous gangue minerals. A little microscopic calcite is also present.

The galena forms rather fine grains and aggregates, both impregnating the rock and partly lining cavities. The cerusite varies from dark gray to white. The dark variety, when treated with hydrochloric acid, yields free chlorine, which suggests that the dark color is due to a manganese oxide. Under the microscope remnants of galena are bordered by a dull black material, which may be a manganese oxide, and this in turn is surrounded by cerusite. In some places the galena has disappeared and only an irregular mixture of the cerusite and the black mineral remains. The white variety occurs in aggregates from which the dark color has been removed, and also in scattered rectangular platy crystals in the cavities. Cerusite also occurs as little veinlets and interstitial grains in the wall rock.

Small specks of oxidized pyrite are scattered among the lead minerals. The quartz is present as a matrix for the ore minerals and as small well-formed crystals lining cavities. As a matrix in leached places it is a white or light-brownish honey-combed material. The barite occurs in typical platy crystals, some half an inch in length, thinly scattered, and mostly but not wholly in the cavities.

The lower Morgan tunnel is a short distance south of the upper tunnel, and extends for 265 feet along a crushed zone in quartzite. The strike of this zone is N. 30° E., and its average dip is about vertical. It has been traced on the surface from the tunnel mouth to the crest of the range, where a small amount of displacement along it is shown by an offset shale bed. The outcrop of the crushed zone has typical gossan stains, but prospecting thus far has shown only a small scattered distribution of lead minerals. Other gossan-stained fissures near and parallel to this one were noted near the crest of the ridge.

Black Hawk mine.—The Black Hawk workings are in the foothills about a mile east of the Morgan workings. The ore thus far found has occurred along faults and adjacent bedding planes. The principal fault trends N. 40° W., between a southwest wall of conglomerate and a northeast wall of quartzite. Branch fissures in the quartzite extend from the fault in various directions, suggesting roughly a radial arrangement. They are all marked by brecciated quartzite. The largest ore shoot found was a layer of partly oxidized galena about 10 inches thick along a bedding plane in the quartzite closely associated with the principal fault and an oblique branch fissure. It was followed in a narrow flat stope for a distance of 30 feet before it pinched to a thin streak. Small bunches of ore and one shoot of workable size have been found in the minor fissures.

The ore seen in the Black Hawk workings was all galena-cerusite in a gangue of brecciated quartzite. No barite was noted.

GENESIS.

Although there is no strong evidence as to the ultimate source of the ores, the relation of ore shoots to fissuring indicates that ore-bearing solutions ascended along faults or crushed zones and deposited ore at points where excessive shattering along a fault or at the intersections of faults with other fissures or

bedding planes allowed the solutions to permeate and replace the rock more thoroughly than elsewhere. All deposits so far discovered are small, and further prospecting is likely to result in the discovery of additional small shoots rather than of persistent ore bodies.

WEST TINTIC DISTRICT.

By G. F. Loughlin.

GEOGRAPHY.

Although the West Tintic district probably includes part of the West Tintic Range the few mines in the district that have produced ore lie to the west, in the low, southern part of the Sheeprock Mountains. The two ranges are separated by the two narrow valleys of Vernon and Cherry creeks. (See fig. 46, p. 424, and Pl. XXXVIII, *B*, p. 377.) Cherry Creek, which flows southward for 6 to 7 miles before disappearing at the northern end of Sevier Desert, is the principal stream and furnishes water for the towns of Mammoth and Robinson in the Tintic district 18 miles to the east, as well as for a few ranches in its valley. The mines of the West Tintic district, however, which are about 3 miles west of Cherry Creek, obtain their water from a well on Hassell's ranch about 1½ miles to the northeast.

The nearest towns to the West Tintic district are Eureka and Mammoth, in the Tintic district. From these towns the district is reached by a wagon road, for the most part of only moderate grade, that extends for 25 miles over a broad pass in the south-central part of the West Tintic Range. Ore may be hauled over this road to Tintic Junction or by a road to the south that extends from Cherry Creek valley to Jericho station on the Los Angeles & Salt Lake Railroad. The distance from the Scotia mine to Jericho is 16 to 17 miles.

GEOLOGY.

The formations in the West Tintic district include Paleozoic and probable pre-Paleozoic sedimentary rocks, and intrusive and effusive igneous rocks of probable Tertiary age. As a rule the sedimentary rocks form the more prominent summits and the igneous rocks the lower foothills, valleys, and some of the broader saddles. (See figs. 46, p. 424, and 47.)

SEDIMENTARY ROCKS.

PRE-CAMBRIAN (?) QUARTZITE.

The thick formation of quartzites, shales, and shaly conglomerates, which forms the bulk of the Sheeprock Range from the Columbia district southward, extends to the southern foothills of the range. In the West Tintic district its southern boundary is an irregular crescent, concave southward, and partly surrounding an area of limestone and dolomite that contains the productive mines and more promising prospects. The quartzite overlies the limestone but (see p. 438) is an overthrust.

The lithologic character of this formation in the West Tintic district is generally the same as in the districts to the northwest. The quartzite members, though much fractured, are the more resistant to erosion and form caps to many of the lower and higher summits, and the conglomerate and shale occupy the slopes and are in large part concealed beneath débris. The quartzite varies in composition from light colored and relatively pure to the dark-brown ferruginous variety so characteristic of the formation. The conglomerate members consist of angular to subangular cobbles or small boulders of older quartzite, schist, and slaty rocks, in a shaly to schistose matrix, and here as elsewhere bears a rather strong resemblance to glacial till. The shale mostly is gray to green, weathering to brown, and of typical structure.

The strike and dip of the formation vary and can be accurately determined at only a few places. The dips as a whole, however, are low to moderate to the north or northeast.

The formation is cut by many veins of white massive quartz, whose outcrops appear barren. They strike in many directions and none of them are traceable over considerable distances.

There is no local evidence to indicate the age of this formation, but as it is continuous northward to the Columbia district, where it underlies quartzite of Lower and Middle Cambrian age, there can be no reasonable doubt that it is either very early Lower Cambrian or pre-Cambrian.

PALEOZOIC LIMESTONE.

Dolomitic limestone, of uncertain age, occupies an area of a few square miles at the southern end of the range, and is surrounded by

the quartzite series except on the south, where it is bordered by alluvium. Its northern boundary is about 1½ miles long and passes just north of the Walker shaft of the Scotia mine. From this northernmost and narrowest part it diverges southward. Its central part forms district to the east. A few bands are cherty. Optical and chemical study shows that much of the unmetamorphosed rock in the West Tintic district is very close to a pure dolomite in composition. The only impurities noted under the microscope are finely divided carbon,

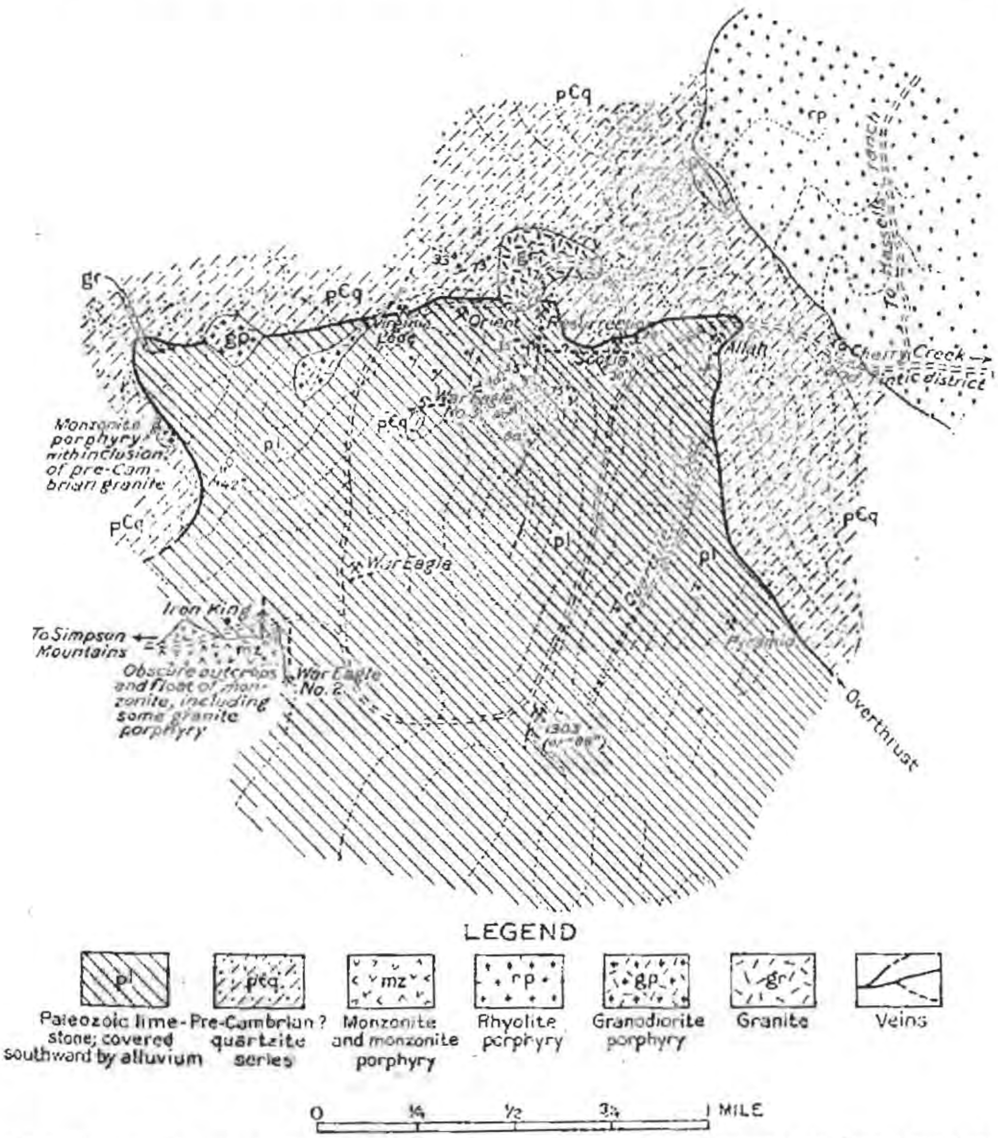

FIGURE 47.—Sketch map showing main geologic features and the locations of mines and prospects in the West Tintic district.

the high north-south ridge southwest of the Scotia mine and also comprises the lower ridges to the east and west.

Where not affected by contact metamorphism it is prevailingly of dark bluish gray and fine grained. Some beds are of very even texture, others are finely banded with lighter gray streaks, and others are spangled with short white markings characteristic of certain Middle and Upper Cambrian dolomites in the Tintic which colors the rock, and a few minute but well-formed quartz crystals.

Where affected by incipient metamorphism the rock is partly or completely bleached to very light gray or white by the elimination of carbon, but the composition is not appreciably affected. Tremolite is the only silicate mineral noted in this phase of the rock. Although it is more abundant in bleached rock it has been noted forming radiating aggregates in

unbleached dolomite. More intense metamorphism nearer the intrusive igneous contacts has developed a number of typical silicate minerals, the most conspicuous of which are garnet and epidote; diopside, tremolite, hornblende, actinolite, phlogopite, titanite, and chlorite are present in fine to microscopic gray to green aggregates, some of which resemble chert in appearance. These metamorphic minerals tend to form abundantly in certain layers and to be bounded by layers of granular calcite. The presence of calcite as the prevailing carbonate in the thoroughly metamorphosed rock is in marked contrast to the prevailing dolomitic character of the unmetamorphosed rock.

A bed of shaly limestone, which marks approximately the upper limit of the ore horizon in the Scotia mine, deserves special mention. At one place along its outcrop, southeast of the Walker shaft, it forms the hanging wall of an old open-cut stope which yielded bonanza ore in the early days and for this reason has been locally called the "bonanza shale." The rock is bluish gray, lighter than the dolomitic rock, microgranular, and very thin bedded to shaly. The thin beds of limestone are separated by shaly partings. Immersion in dilute hydrochloric acid yields brisk effervescence, proving a general absence of dolomite, and the abundant residue after solution consists chiefly of fine quartz grains and sericite flakes.

Cherty beds have been noted in the eastern and northwestern parts of the limestone area. A few thin intercalated beds of quartzite in the vicinity of the eastern beds are much fractured and filled with comby quartz veins. The most prominent of these extends northward with approximately vertical dip, along the top of the low ridge east of the road between the "1903" and the Scotia mines (fig. 47) to the saddle southeast of the Scotia mine, where it passes beneath the contact of the limestone and pre-Cambrian (?) quartzite series. A few sandy beds were noted between the south end of the high limestone ridge and the road junction to the west.

No determinable fossils have been found in the limestone area. The only characteristic markings in the central and eastern parts of the area are the short white spangles, similar to those in the Middle and Upper Cambrian limestone of the Tintic district, which appears in a few beds. These with the prevailing dolomitic character suggest correlation with Cambrian; but as later Paleozoic limestones, including those of Mississippian age, are also conspicuously dolomitic, no definite age is assigned to the rock. The black chert nodules near the northwest corner of the limestone area strongly suggest lower Mississippian age.

IGNEOUS ROCKS.

GENERAL CHARACTER.

The igneous rocks of the West Tintic district consist of stocks and dikes of granitic and monzonitic rocks, extensive bodies of extrusive rhyolite, and doubtless latite, the extrusive equivalent of monzonite, though no well-defined outcrops of this were recognized. The granitic rocks comprise one inclusion of pre-Cambrian granite and stocks, dikes, and sills presumably of Tertiary age. The monzonitic rocks are also assigned to the Tertiary. No contacts between the Tertiary granitic and monzonitic rocks have been found.

PRE-CAMBRIAN GRANITE.

Pre-Cambrian granite is represented by an inclusion 3 or 4 feet in diameter in a monzonite porphyry dike, which cuts the quartzite series near the western boundary of the limestone area. (See fig. 47.) The granite is pink, rather coarse grained, and somewhat gneissoid. It consists of pink alkalic feldspar, white plagioclase, and quartz, the last two obscured by fine granulation. A small quantity of chlorite after biotite is also present. As seen in thin section the principal minerals are microperthite, calcic oligoclase, quartz, and chlorite. The usual minor constituents are present, and one allanite crystal associated with epidote was noted. The section is traversed by several microscopic crushed zones, and in this respect is markedly different from the intrusive granite of the district. The presence of this inclusion suggests that a portion of the granite which is known to underlie the quartzite series in some parts of the State is present in the segment overthrust upon the limestone, though not exposed at the surface.

TERTIARY INTRUSIVE ROCKS.

Character and distribution.—The intrusive rocks of the district vary in appearance but are for the most part very similar in chemical composition and fall in the granodiorite or

quartz monzonite groups. The most alkalic (salic) variety noted is a muscovite granite, and the most ferromagnesian (mafic) variety is a dioritic phase of monzonite.

The intrusive bodies are for the most part small, and most of them are grouped in an east-northeast zone near the northern boundary of the limestone area. A small complicated stock, much obscured by débris covering, is present in the southwest part of the area, and dikes of granite porphyry and monzonite porphyry are very abundant, most of those noted trending a little east of north or a little north of east. No distinct age relations have been found.

Granodiorite group.—A stock of roughly triangular outline is exposed along the curving ridge northwest of the Scotia mine. It consists mostly of light-gray coarse-grained, considerably disintegrated rock, with minor varieties of aplite and granite porphyry along the border. Contact metamorphism along its border is expressed by induration of shale beds in the quartzite and by slight alteration in the adjacent part of the limestone. The mineral composition and texture of the coarse-grained rock is essentially similar to that of the larger granodiorite in the Columbia-Erickson district to the northwest and on Desert Mountain to the southwest.

The border porphyry phase is of interest for comparison with the variations in the other stocks. It consists of a very fine grained groundmass with prominent rounded grains of quartz, the largest of which are 3 millimeters in diameter, white crystals of altered feldspar, and a few weathered scales of biotite. It differs from the main body of the stock merely in the smaller size of most of its components. In thin section the quartz phenocrysts show some resorption, and their corroded edges are fringed with secondary quartz, which is accompanied by a little calcite and sericite. The plagioclase crystals (An_{35-45}) are considerably altered. Biotite phenocrysts are altered to a mixture of chlorite and calcite, with or without sericite. The groundmass consists of fine graphic intergrowths of quartz and alkalic feldspar inclosing some short laths of plagioclase (oligoclase-andesine). A few spherulites consisting largely of quartz are associated with the graphic intergrowths.

The narrow wedge-shaped stock to the west crosses the overthrust without displacement and ends northwestward as a sill in the quartzite series. Another small stock just west of this one also cuts the overthrust. These two stocks consist of granodiorite porphyry, with prominent phenocrysts of feldspar but none of quartz in an aplitic groundmass. A small amount of altered biotite and 3 or 4 per cent of oxidized pyrite grains are also present. In thin section most of the plagioclase is too much sericitized to be identified, but a few grains indicate calcic andesine. Biotite is altered to chlorite. The groundmass consists of quartz and feldspar, mostly in graphic intergrowth. The feldspar is much kaolinized but appears to include both alkalic and plagioclase varieties, the latter less calcic than the plagioclase phenocrysts. The pyrite is associated with sericite, secondary quartz, and chlorite, and is clearly an alteration product. This rock differs from that first described mainly in the absence of quartz phenocrysts, though it contains a large amount of quartz in the groundmass.

Another small stock (not accurately outlined in fig. 47) outcrops to the southeast just west of the overthrust contact. This rock is light pink and composed of plagioclase, biotite, and a few hornblende crystals with scattered fine grains of magnetite and titanite in an extremely fine grained groundmass. In thin section the feldspar phenocrysts prove to be mostly plagioclase with a few of microperthite ($Or_{80}Ab_{20}$). The plagioclase includes two varieties; large crystals of labradorite (An_{60}) partly resorbed, and oligoclase (An_{25}) in relatively small grains and in one place forming a rim around an older labradorite. Biotite and common hornblende are typical and considerably chloritized. The groundmass consists of abundant quartz and alkalic feldspar (microcline microperthite), with a less amount of sodic plagioclase. Minor constituents include magnetite, titanite, apatite, and zircon.

A dike of muscovite granite, which trends N. 25° W. across the overthrust contact in the extreme northwest corner of the limestone area, is nearly white, fine, even grained, and composed of white feldspar, colorless quartz, thinly scattered muscovite, and some flakes of biotite. As estimated in thin section, the feldspars comprise about 55 per cent, quartz 40 per cent, and muscovite and minor accessories 5 per cent. Four-fifths of the feldspar is perthitic microcline with small unoriented

inclusions of plagioclase. The remainder is plagioclase—oligoclase-andesine (An_{30}) with more sodic outer zones. The muscovite tends to form poikilitic crystals inclosing small well-crystallized grains of quartz, and appears to have been on the whole the latest important mineral to crystallize. The minor constituents noted are biotite, separate or intergrown with muscovite, magnetite, and zircon.

The composition of this rock is very similar to that of the groundmass of the rocks previously described (p. 435). Those rocks contained no primary muscovite, but the presence of muscovite in this rock may well be attributed to a greater concentration of water and fluorine in a salic portion of magma and does not necessarily indicate the intrusion of a distinct magma. In other words, the muscovite granite is regarded as a salic differentiate from the granodioritic magma.

The large area of granite porphyry and rhyolite porphyry northeast of the limestone area has the same general composition as the granodioritic rocks, but part of it differs in possessing textures characteristic of effusive rocks. In spite of these textures all the contacts with the quartzite series on the west are nearly vertical and intrusive. To the east, however, the rocks are in part clearly extrusive, and it is concluded that the main vent through which the lavas of the region were erupted is in the western part of this area.

The greater part of the rock in this vent varies in texture from very fine grained porphyry to rhyolite porphyry, although several eruptions are represented. Much of it is light gray, dense porphyritic, and contains abundant phenocrysts of quartz and feldspar, with a little biotite and magnetite. In thin section the quartz phenocrysts show resorption and many of them are cracked or even "faulted," the groundmass filling the fractures. The feldspar forms roughly rectangular grains, some of them with resorbed rims. Plagioclase (andesine) is somewhat more abundant than alkalic feldspar, a few grains of which have a poorly defined structure suggesting microcline. Biotite and minor accessories are typical.

Another rock in the vent, intrusive into the one just described, is of dark-purplish color and somewhat denser texture but is essentially identical in mineral composition. The appearance of this rock is also characterized on the surface by the pink color of the alkalic feldspar. This color disappears a fraction of an inch away from the surface or from fracture lines, and is clearly the result of weathering.

Several dikelike intrusions of rhyolitic rock in this area were noted along the road that extends northward and eastward by Hassell's ranch to the divide between Vernon and Cherry creeks, but none were studied in detail. A special variation, however, is represented by the narrow body of rhyolite breccia that cuts the quartzite series vertically just west of the main area. (See fig. 47.) This rock is purple to gray, finely fragmental, and consists of banded to massive fragments of rhyolite in a fine matrix of the same material. Its chemical and mineral composition is shown by the microscope to be similar to the rocks of the main area, from which it differs only in texture.

Monzonite.—The only stocklike body of monzonite in the immediate vicinity of the mines is in the southwest part of the limestone area and is so obscured by débris of rhyolitic or granodiolitic porphyry that its exact outline and structural relations are not easily determined. Dikes and sills of monzonite porphyry have been noted at several places throughout the limestone area. The typical monzonite is gray, medium, and even grained, and consists chiefly of gray translucent feldspars, biotite and augite, the augite being more or less altered to hornblende. Both feldspars are recognizable megascopically, plagioclase as a rule forming gray or white lath-shaped twinned crystals which are surrounded by alkalic feldspar of slightly different color and with no definite crystallographic outline. Pyrite is present as small grains scattered through the rock and also as thin films or sheets along fracture planes. In thin section the plagioclase presents a marked zonal growth, the zones ranging in composition from An_{50} to An_{25} or heing even somewhat more sodic. They average about An_{35}. The alkalic feldspar, which has a very fine perthitic structure, forms irregular grains of various sizes. Some of the smaller form partial rims around plagioclase, and the larger ones have a poikilitic character, inclosing crystals of all the other primary minerals except quartz. Quartz forms irregular grains, some of which are a millimeter in diameter, mostly interstitial to the other minerals but in part forming micrographic intergrowths with alkalic feld-

spar. The microscopic quartz amounts to nearly 10 per cent of the rock. Biotite forms typical grains, some with resorbed margins. Augite forms prismatic grains averaging about a millimeter in length and showing all stages of the transition from fresh augite into compact green hornblende with typical cleavage and pleochroism. Some of the augite (or hornblende) grains are intergrown with biotite. Minor accessories include rather abundant titanite and magnetite in irregular to hypautomorphic grains, apatite in typical well-formed prisms, and rarely zircon.

Besides the typical rock variations of dioritic character are present in the monzonite stock. Some are feldspathic; others have a preponderance of black minerals. In the feldspathic variety the plagioclase has about the same composition as in the typical monzonite, but alkalic feldspar and quartz are very scarce. Biotite is the principal accessory and is accompanied by a little uralitic hornblende (after augite?). The darker variety consists of zonal plagioclase, averaging near An_{50} in composition, and primary hornblende accompanied by a little biotite. No augite is present. Alkalic feldspar and quartz form fine interstitial aggregates among the predominant minerals. Magnetite, titanite, and apatite, the first two frequently of megascopic size, are conspicuous minor constituents in both varieties.

Alteration.—Alteration has affected all the igneous rocks of the district to a greater or less extent, but the kind of alteration is the same in all of them and is of the propylitic type. The common alteration minerals are sericite, chlorite, epidote, calcite, quartz, and pyrite, and these are accompanied in some of the rocks by uralitic hornblende, secondary titanite, and magnetite. The relations of these minerals to one another show that they were formed at the same time, and they are attributed to the action of heated waters that permeated the rocks during ore deposition. Kaolin and limonite are the principal minerals formed since that time by surface weathering.

Paragenesis.—The different intrusive rocks of the district are closely related. In some the more calcic plagioclase and the black silicates are concentrated in relatively large proportions; and in one, the muscovite granite, the quartz and alkalic feldspars are especially concentrated. The plagioclase is contained mainly in the phenocrysts or earlier-formed minerals and the alkalic feldspars mainly in the groundmass or later-formed minerals of the intermediate (granodioritic) rocks of the district. Sufficient time to allow certain degrees of concentration of the earlier groups of minerals before the later groups began to crystallize accounts for the variations in composition and for the different textural characteristics of the rocks.

TERTIARY EXTRUSIVE ROCKS.

The principal area of extrusive volcanic rocks extends eastward from the vent already described across Cherry Creek valley, 3 miles distant, and partly up the west slope of the West Tintic Range. Small isolated areas lie on the east slope of the range. The rocks, so far as noted, are prevailingly rhyolitic and include flows and breccias, but as they are some distance from the mining district proper they have not been studied in detail.

STRUCTURE.

FOLDING.

The exact structure of the limestone has not been determined. The strata at the Scotia mine dip 20°–25° N. and appear to lie conformably beneath the quartzite series. South of the Scotia mine, along the high limestone ridge, they strike north-northeast and dip very steeply west. On the low ridge to the east they strike similarly but dip from vertical to steeply east. These relations, together with the distribution of the cherty zone, suggest a sharp anticline with a north-pitching axis approximately along the road between the "1903" and the Scotia mines and through the Scotia property. In the limestone area west of the high ridge débris coverings and metamorphism greatly conceal the structure. Near the west contact, across the ridge southwest of the Orient shaft, there is some indication of a local pinched syncline, but the attitude of the beds as a whole is the same as those on the high ridge. The available data suggest a major anticline with nearly vertical limbs, whose axis is about halfway between the middle of the limestone area and its eastern contact with the quartzite series.

OVERTHRUST.

The structure of the limestone is thus unsymmetrical with respect to the quartzite series, and other discordances in position exist between the two rocks along the contact. The disappearance of the thin quartzite bed in the eastern limestone area beneath the great quartzite series has already been mentioned. This structure either implies the very rapid pinching out of some hundreds of feet of limestone and their equally sudden reappearance just to the north, or is due to an overthrust. The attitude of the beds is apparently conformable at the Scotia mine, but a shale member, which immediately overlies the limestone, is beveled off both to the east and west. At the saddle between the Scotia and Orient mines a small mass of quartzite rests on limestone, the contact dipping northeast at a low angle. Just south of this point, on the high limestone ridge, the limestone strata strike a little east of north, but the limestone-quartzite contact continues westward across the Orient and Virginia Lode claims without regard to the strike and dip of the limestone. At the Virginia Lode prospect the limestone is separated from a shale member of the quartzite by a nearly vertical east-west fault. From this point westward the contact is complicated by two small stocks and a few dikes of granitic and monzonitic rock.

At the northwest corner of the limestone area the limestone strikes N. 25° W. and dips nearly vertically, but the quartzite contact curves from east to west through an angle of about 115° to a trend paralleling the limestone bedding. Southward along the west contact the attitude of the limestone beds varies. At one place, at the head of a small branch gulch in a southwest direction from the Virginia Lode prospect, the limestone close to the contact strikes N. 40° E. and dips 42° SE., whereas the contact strikes about north. The limestone is much contorted and somewhat metamorphosed. From this point southward the contact extends along the crest of a low south-sloping ridge, until the ridge surface sinks below it, leaving only limestone, and thus proving that the plane of contact along this ridge dips west at a low angle, away from the dip of the limestone. The limestone at some places along the contact is overlain by quartzite and at others by shale. Both the limestone and quartzite are scattered at several places along the contact.

Within the limestone area a low ridge south of the War Eagle No. 3 open cut is capped by quartzite but consists otherwise of steeply dipping limestone whose exposures surround the quartzite. The quartzite is not intercalated in the limestone and is regarded as a remnant of the great quartzite series which once overlay the limestone.

The evidence, although obscured along much of the contact by débris, all points to discordant relations between the limestone and quartzite, which, coupled with the stratigraphic evidence already given, indicates an overthrust fault of undulating character. The limestone area was completely covered by the quartzite at one time, the fault contact arching over it. To regard the contact as an unconformity would necessarily imply an immense thickness of pre-Cambrian limestone in the West Tintic district and nowhere else in the Great Basin region. Furthermore, no fragments of the limestone and only pebbles and cobbles of siliceous sediments have been found in the overlying quartzite, whereas the structural details of the contact are indicative of disturbance.

Results of a brief reconnaissance in the West Tintic Range along the Tintic Road lend support to the foregoing interpretation. Along the road the sedimentary rocks consist of quartzite with intercalated beds of shale and limestone dipping westward at a low angle. Fossils collected from two limestone beds were determined by G. H. Girty, as follows:

Bed southwest of Summer ranch: Sponge?, *Zaphrentis?* sp., *Bellerophon* sp.

Bed 100 yards north of the Mammoth reservoir: *Zaphrentis* sp. and *Lithostrotion whitneyi*.

Mr. Girty states that these faunas are too scant and too poorly preserved to be assigned to any definite horizon, but he regards them as probably upper Mississippian.

Along the crest of the range north of the road and on its west slope down to the divide between Cherry and Vernon creeks lie coarse conglomerate and quartzite of pre-Cambrian (?) age, whose western dip suggest that they formerly extended over the upper Mississippian quartzite and that the overthrust extends as far eastward as the crest of the West Tintic Range. Their exact trend in the West Tintic Range, however, can be determined by detailed work alone, much of their surface being covered by disintegrated volcanic

rocks and care being necessary to distinguish the light-colored quartzite members in the pre-Cambrian (?) from beds of similar appearance in the upper Mississippian (?) formation. The stratigraphic and structural relations of the rocks in the West Tintic Range and the West Tintic mining district are shown in figures 46 (p. 424) and 47 (p. 433).

The age of the overthrust is clearly greater than that of the Tertiary igneous rocks but can not be definitely determined on local evidence. It may be contemporaneous with the overthrusts in the Wasatch Range, which are of Cretaceous age.

FAULTING AND FISSURING.

With the exception of the overthrust already described, faults of considerable displacement are not conspicuous. Those actually exposed and also those strongly suggested in the field lie in two systems that trend nearly north and nearly east. A porphyry sill at the small iron-ore prospect on the Virginia Lode claim is displaced 3 feet by a north-south fault with a 60° dip, and a well-defined east-west fault with nearly vertical dip is exposed just to the west. Its strike coincides with the limestone-quartzite contact, but its vertical dip suggests that it may cut the plane of the overthrust at this place. Another fault, which trends nearly north, is suggested by a deflection of the overthrust contact east of the Resurrection (Prairie Bell) prospect but has not been traced northward or southward. Other faults of similar trends are suggested at a few places by apparently discordant relations of the strata. None of them are closely connected with ore deposits.

Mineralized fissures also follow two prevailing directions: N. 15°–20° E. with vertical dip and N. 70° E. with steep southerly dip.

HISTORY AND PRODUCTION.

No satisfactory account of the production of the West Tintic district can be given, for in the earlier years its output was included by the Director of the Mint with the Tintic district. The Scotia mine has been undoubtedly the largest producer, but accurate data of its output are not available. According to W. W. Riter, of Salt Lake City, who was one of its original owners, the first pocket of ore, found about 1870, amounted to about 250 tons of 65 per cent lead ore containing a moderate proportion of silver. This ore was shipped to Swansea, Wales, and to smelters south of Salt Lake City. In 1871 the property was sold to Joab Lawrence and associates, who joined in building the Homansville smelter in the Tintic district. This enterprise failed, and the smelter was moved away in 1872. The mine later passed into the hands of the Boston-Tintic Mining Co., by whom it has been worked or leased intermittently. The production of the Scotia mine since 1880 has probably amounted to somewhat more than 3,000 tons, valued at about $150,000.

From 1902 to 1913 only two mines shipped ore, both in small amounts.

ORE DEPOSITS.

GENERAL CHARACTER.

The ore deposits of the district comprise several types, transitional into one another, which indicate deposition at temperatures ranging from those existing along the margins of crystallizing intrusive rocks down to moderate and even low. All the types are in limestone, in or closely associated with fissures, some of which coincide with the bedding of the rock.

The deposits formed at highest temperatures are of the contact-metamorphic type. More or less contact metamorphism has been produced around all the larger ore bodies of granodioritic and monzonitic rocks and also along some of the dikes and sills. The most intense metamorphic effect is just north of the monzonite stock in the southwest part of the limestone area, and the only contact-metamorphic ore body of much promise—that of the Iron King mine—is in this place.

MINES.

IRON KING MINE.

The workings of the Iron King mine are in both metamorphic limestone and monzonite and cut dikes of granite porphyry. The mine in 1913 was opened by a shaft 200 feet deep and by 200 feet of drifts, but the underground workings were not accessible when visited. A part of the ore body, however, was exposed

along a narrow deep open cut. The ore body forms a vertical band a few feet thick, parallel to the vertical north-south bedding.

The most conspicuous ore minerals are magnetite and specularite, which form an apparently solid mass, colored in places by green copper stains. Some specimens are of magnetite, others of hematite, and both varieties contain disseminated grains and well-defined veinlets of pyrite. No chalcopyrite was recognized, and the green copper stains may have been derived from copper in the pyrite. A small shipment in 1913 contained two classes of ore, one carrying 0.282 ounce of gold and 2.6 ounces of silver to the ton, 6.2 per cent copper and 40.9 per cent iron; and the other carrying 0.15 ounce of gold and 1.55 ounces of silver to the ton, 3.15 per cent copper and 48.8 per cent iron.

The margins of the ore show replacement of an epidotic phase of the metamorphic limestone, a relation which indicates that the ore was formed at a later stage of contact metamorphism than were the silicate gangue minerals. The silicate rock, as shown by specimens on the dump, is also cut and replaced to some extent by vein quartz and calcite, which imply that mineralization continued after the temperature had fallen below the range at which the silicates had formed.

VIRGINIA LODE.

Another type of contact-metamorphic ore that has been prospected on the Virginia Lode claim is pyritized shale along the hanging wall of a porphyry dike. Oxidation has decomposed the pyrite and concentrated the iron along the margin of the dike in the form of limonite in a layer ranging from a thin film to 6 feet thick. A similar deposit of limonite has been opened in a prospect tunnel on the Allah property east of the shaft. No assays of either ore were obtained. Deposits of this type may be mistaken for the weathered outcrops of a silver-lead deposit, but it is improbable that valuable silver-lead deposits will be found in either shale or quartzite.

WAR EAGLE CLAIMS.

Closely related to the magnetic ore of the Iron King mine is that of the War Eagle No. 2, which forms a north-south vein a short distance to the east. The vein is opened by a shaft 70 feet deep, with short drifts on the 25 and 70 foot levels. The vein sends short tongues into the wall rock, which includes both metamorphic limestone and silicified granodiorite porphyry. Monzonite is exposed in surface workings near the vein. The ore thus far found occurs in small bodies, from one to a few tons in weight, of barren or low-grade massive quartz associated with branch fissures at their junction with the main vein, between stretches. The primary ore mineral is chalcopyrite in irregular patches, usually in a matrix of fine-grained specularite. The gangue mineral is quartz, with local developments of barite and calcite. Chalcopyrite also forms scattered grains or bunches in milky quartz and occurs as narrow bands alternating with cherty replacement quartz. Some bunches of lead ore are present, but no primary lead minerals have been found. The chalcopyrite is largely oxidized to a dark resinous or pitchy form of limonite and to malachite and chrysocolla. The oxidized lead ore, with which some copper minerals are mixed, consists of cerusite and bindheimite (hydrous antimonate of lead) and probably a little anglesite, accompanied by small amounts of the zinc minerals, most conspicuous of which is aurichalcite. This ore, which is characterized by the yellow color of the earthy bindheimite and is locally called "chlorides," is rich in silver, and one small sample is said to have assayed 821 ounces to the ton. Both lead and copper ores contain more or less black manganese oxide. Secondary gangue minerals are finely crystalline to chalcedonic quartz and calcite.

The War Eagle claim, a short distance northeast of the War Eagle No. 2, contains copper ore similar to that just described except that it lacks specularite. The workings are opened by an inclined shaft 200 feet deep sunk along the hanging wall of a granite porphyry dike, along which bunches of ore were found. A drift on the 200-foot level follows a vein trending S. 70° W., which also follows a dike hanging wall. A winze from this level follows the dip of the vein, which is said to expand downward to a width of 4 feet and to contain rich ore some of which assays 13 per cent copper and 200 ounces of silver to the ton. The average content is said to be about 4 per cent copper and 16 ounces of silver to the ton.

On the War Eagle No. 3 prospect, considerably farther north, a vein trending N. 75° E. and dipping from vertical to steeply north has been mined from the surface for lead ore, but the workings were not accessible when visited. Ore seen on the surface consists of galena partly oxidized to cerusite, accompanied by white patches of calamine, a little microscopic smithsonite, and brown and black stains of limonite and wad. The principal gangue at the surface is calcite in banded columnar masses (travertine), which extend in places 2 feet into the footwall of the open cut. The general run of ore is said to have been accompanied by soft red iron oxide. Its silver content is not stated, but gold to the value of $5 a ton has been reported.

The relations of the three War Eagle prospects indicate that the temperature of ore deposition decreased northward. Though not along a single vein, it seems probable that the three prospects are connected by a system of intersecting approximately north-south and east-west fissures. The mineral composition of the War Eagle No. 2 ore indicates a high temperature, though not so high as that required for contact-metamorphic ore; the nonsiliceous type of lead-zinc ore at the War Eagle No. 3 is characteristic of deposition at relatively low temperatures.

ORIENT WORKINGS.

The Orient workings, north of the War Eagle No. 3, were inaccessible. On the dump was a small pile of oxidized copper-iron ore and some metamorphic limestone with a few green copper stains. No primary ore was found.

"1903" OR "1888" MINE.

The "1903," formerly the "1888," mine, near the southeast base of the high limestone ridge, is of particular interest because of its varied character. It is opened by an inclined shaft 140 feet deep and by 150 feet or more of drifting on the 45-foot level, mostly east of the shaft. The country rock is dolomitic limestone, partly metamorphosed, with steep eastward dip. Quartzite, which outcrops west of the shaft, is said to be cut by a short winze from the west end of the 45-foot level.

The deposit consists of a N. 15° E. quartz vein, parallel to the bedding, intersected at the shaft by an east-west mineralized fissure with southerly dip. The quartz in the main vein is mostly dense and cherty but is well crystallized around cavities. In a shallow pit 200 feet north of the shaft the vein consists of quartz, barite, and galena. The barite forms a network of platy crystals, and the quartz and galena fill the interstices, impregnate the barite crystals, and fill cracks in them. Pyrite and a few specks of zinc blende are minor constituents. A little cerusite and secondary quartz are also present.

The material in and close by the cross fissure, which is followed by the shaft, is mainly quartz-fluorite-galena ore, accompanied in places by quartz-chalcopyrite-galena ore. The variety containing chalcopyrite resembles that from the War Eagle vein, but its galena is more conspicuous. The chalcopyrite forms relatively pure large grains or masses some of which are 2 inches in diameter; and the galena forms fine-grained aggregates inclosing a few small grains of chalcopyrite. The quartz is fine grained and resembles quartzite and chert. The fluorite variety consists of rather coarse-grained fluorite and galena in a matrix of cherty quartz, which in places is apparently absent. The ore cut in the shaft and along the drift to the east was 1 to 4 feet thick and contained an average of 22 per cent lead. The principal shoot is a heavy galena ore of this general type on the east or hanging side of the main vein, about 30 feet north of the drift along the cross break. It lies between two bands of chert-tremolite rock and extends upward from the level at 45° N. 5° E. The walls of the stope are of low-grade fluorite-galena ore with varying amounts of quartz.

The composition of the ore mined is as follows: Gold (trace), silver 1.3 ounces to the ton, lead 46.8 per cent, copper 0.2 per cent, insoluble 17.1 per cent, sulphur 5.1 per cent, iron 1.2 per cent, lime 26.1 per cent. The ratio of lead to sulphur indicates that four-fifths of the lead was present as galena. The low silver content of this slightly oxidized ore is in striking contrast to the high content in the thoroughly oxidized antimonial lead ores of the War Eagle No. 2 and Scotia mines.

A variety of ore containing barite, carbonate, and galena, noted only on the dump of the "1903" mine, forms bands in and contains inclusions of the quartz-galena ore. The barite forms a typical network of plates, and the other minerals fill the interstices. The

carbonate is mostly calcite, which incloses small rhombs of ferruginous dolomite.

Secondary ore minerals are limonite, malachite, chrysocolla, cerusite, and calamine, the calamine indicating the former presence of a considerable though minor amount of zinc blende. The secondary gangue minerals are drusy quartz, calcite, and aragonite in the form of tufts of needles on the secondary calcite.

The different types of primary ore in the "1903" mine include most of those found in the entire district. The chalcopyrite-galena type represents a transition from deposition at rather high to moderate temperatures; the fluorite and the barite-quartz types are believed to represent deposition at moderate temperatures, and the barite-carbonate type represents a still lower temperature, and, from its structural relations, appears to mark the last stage of deposition. Failure to find the fluorite and barite-quartz types in contact prevents a statement as to their relative ages. The fluorite type has not been found in any other mine in the district.

ALLAH PROSPECT.

The quartz-barite-galena type of ore is also represented a mile north of the "1903" mine by the veins on the Allah property. One vein, 4 or 5 feet wide, strikes N. 10° E. and dips 80° W. and is associated with two east-west veins traceable for considerable distance by float. Very little prospecting has been done on these veins. Besides the well-defined veins several small bunches of similar composition are exposed on the surface and in the 198-foot shaft and appear to be local enlargements of tight fissures or at the intersections of fissures. No ore has been mined on this property, but the well-defined veins merit more attention than they have received. The presence of limonite similar to that in the Virginia lode was mentioned on page 440.

SCOTIA MINE.

The deposits in the Scotia mine, at the northeast base of the high limestone ridge, are associated with a strong quartz vein that trends S. 65° W. to the south of the Walker shaft and with north-south fissures that have been followed from the shaft northward. The vein has been developed by a few shallow inclined shafts and by about 450 feet of drifts, inaccessible when visited; and the north-south fissures have been opened by a 150-foot vertical shaft and by drifts and inclines on the 50, 86, and 150 foot levels.

The quartz vein, called the "Blue Jay" vein, trends S. 65° W. closely parallel to a monzonite porphyry sill, and probably connects with a N. 15° E. vein which extends along the east slope of the high limestone ridge and on which the Resurrection (Prairie Bell) prospect is located. The Blue Jay vein dips 70°–80° N., but its vertical extent is not known. Workings beneath it on the 50-foot level were inaccessible, and those on the 150-foot level have not exposed any prominent quartz veins. The quartz of the vein varies from the fine-grained replacement type to milky and well-crystallized varieties. It contains fine grains of pyrite, and much of it is stained with malachite, azurite, light-green copper arsenates, and an unnamed hydrous lead arsenate, perhaps the equivalent of the antimonate, bindheimite. It is, so far as seen, of low grade but has yielded some very rich ore from its hanging-wall side. The principal ore shoot is now represented by the "Bonanza" open cut, which extends downward across the bedding of a shaly limestone, known as the "bonanza shale," into the underlying limestone. This rock, at the open cut, dips 40°–45° N., steeper than elsewhere on the property and, together with the shattered character of the rock, indicates considerable disturbance along the vein fissure. The ore impregnated the laminae of the shaly rock and evidently replaced the limestone below. The shaly character of the rock may have had some influence on the gold content. (See p. 394.) Oxidation, however, further concentrated the metal contents, which ran well in gold, silver, and lead. A short distance west of the "Bonanza" open cut the shaly horizon has been explored by inclined shafts and drifts, and considerable silver-lead ore containing some copper and up to $33 to the ton in gold is said to have been mined from them. These old workings were inaccessible in 1913.

The ore associated with the fissures trending N. 15° E. has been followed from the 86-foot level, west of the Walker shaft, northward and downward below the 150-foot level. The ore horizon, 70 to 80 feet thick, is in the limestone below the "bonanza shale" and above a fine-grained granite porphyry sill. The primary

ore minerals are galena, jamesonite, pyrite, arsenopyrite, and a little chalcopyrite and zinc blende; the secondary minerals are cerusite, anglesite, bindheimite, a hydrous lead arsenate, limonite, and hematite, pharmacosiderite and scorodite. The primary gangue minerals are replacement quartz, which has replaced limestone, and scalenohedral calcite; the principal secondary mineral is calcite in crusts and flat rhombohedrons.

The main ore body begins opposite the shaft on the 86-foot level, where it consists of a little galena and black replacement quartz in a mass of soft hematite. Mineralized ground was worked from this point northward for 170 feet to a cave which contained several loose boulders of high-grade ore. A small stope extends from the west end of the cave, following a northerly fissure down to the 150-foot level, below which small amounts of ore have been found close to the fissure. A short distance north of the cave, at the top of No. 6 raise, a remnant of ore consists of lenses of galena and jamesonite, partly oxidized, along a silicified bed. Considerable arsenopyrite and pyrite ("sulphides"), said to have formed a casing around the galena-jamesonite ore, have been mined in this vicinity, but little of them was in sight in 1913. The arsenopyrite is partly oxidized to the hydrous arsenates, pharmacosiderite and scorodite, and to earthy hematite and limonite.

On the 150-foot level two northerly fissures, one on either side of the shoot just described, have been followed along inclined winzes. Both are accompanied by small bunches of rather fine grained galena with a little pyrite and zinc blende and some copper stains. Quartz is inconspicuous, and calcite is the principal visible gangue mineral. These bunches are formed mostly along bedding planes close to the fissure and just above the porphyry sill. The eastern fissure lies about 80 feet from the main stope, and the bedding planes of the intervening ground contain small amounts of sulphides, especially pyrite. The western fissure, 90 feet from the main stope, is not so clearly related to it.

The ore content north of the shaft has in general ranged as follows according to smelter returns: Gold 0.19 to 0.35 ounce and silver 16.85 to 34.65 ounces to the ton, lead 26.7 to 54.75 per cent, iron 5.45 to 15.55 per cent, insoluble 2.45 to 9 per cent, zinc 1.4 to 3.3 per cent, sulphur 0.7 to 3.8 per cent, and speiss[1] 26 to 41 per cent. The percentages of sulphur show that most of the ore was oxidized. Some "boulder" ore from the cave is said to have contained 60 per cent lead and 200 ounces of silver to the ton, and the oxidized arsenopyrite ore from $10 to $15 of gold to the ton.

The changes in mineral composition of the ore imply that the northern part is farthest from the source and that the metal contents of the ore decrease in value northward, especially as very little oxidation has taken place below the 150-foot level. From this it may be inferred that the ore solutions came from the south, possibly from the "Blue Jay" vein; but no connection with this vein has been established, and the fact that other low-grade quartz bodies have been found but not explored suggests that the ore was introduced through some nearer channel.

CONCLUSIONS.

The ores of the West Tintic district include several varieties which grade into one another. They were introduced through two intersecting systems of fissures, one trending N. 65°-75° E. and the other N. 15°-20° E. They doubtless followed the more open courses along these fissures, and formed deposits only in those that varied in dimensions. The deposits as a rule are small bodies formed where conditions were especially favorable to replacement of limestone. It is a striking fact that the largest deposits studied are not in the vein proper but are adjacent to it in easily replaceable rock, shattered zones, or along branch fissures. This relation is illustrated in the War Eagle No. 2 by the small shoots of high-grade ore, in the "1903" mine by the galena shoot, and in the Scotia mine by the "bonanza" open cut and perhaps by the ore body north of the Walker shaft. The fact that the Scotia ore body is larger than the others is attributed to the unmetamorphosed state of the limestone and to the introduction of the ore between an impervious roof and floor. The size of this ore body, however, is small when compared to those in the average mines of the leading districts, and it must be concluded that ore deposition in the West Tintic district has taken place

[1] See footnote, p. 412.

on a correspondingly small scale, and under conditions that did not favor the concentration of deposition in a few main channels.

The work done justifies the conclusion that with more favorable transportation facilities the district could maintain a small steady output, but that under present conditions there is little hope of steady production.

DESERT MOUNTAIN.

By G. F. Loughlin.

Desert Mountain, or, more appropriately, the Desert Hills, include a cluster of low bare peaks which lie about 12 miles southwest of the West Tintic mining district. The nearest railroad station is Jericho, about 20 miles to the east. (See fig. 46.) There is no water at Desert Mountain; the nearest supplies are at Judd Creek, 8 miles north-northwest, on the road to Simpson Mountains, and at Cherry Creek in the West Tintic district, 12 miles east.

GEOLOGY.

Only the western face of the mountain was visited. The rock here is mostly a light-gray granite cut by a few diabase dikes. Apophyses from the granite are intrusive into a dark quartzite which has not been studied closely, but which presents the same dark colors on weathered surfaces as does the pre-Cambrian(?) quartzite series of the Sheeprock Mountains and the southern Simpson Mountains. The quartzite is exposed at the southern and northern end of the mountain and in low knolls which extend to the northeast. Detritus from the principal valley which drains the southern part of the mountain area contains a large number of pebbles of volcanic rocks (mostly rhyolitic), but no extrusive rocks were seen in place.

The granite is light gray and ranges in texture from even grained to porphyritic. The main body is much crumbled on the surface, is medium grained, and in places contains phenocrysts of alkalic feldspar (microcline) and of quartz half an inch in diameter. Its principal minerals are white feldspar (both plagioclase and microcline), gray glassy quartz, and black to brownish flakes of biotite. Another type is an aplite which forms dikelike and irregular masses in the main body, to which it is similar in color but is much finer grained. It is fresh even close to the surface and in addition to the above minerals contains a small percentage of muscovite. It also contains phenocrysts of feldspar and quartz, few of which are conspicuous. Many of the aplitic dikes have coarse-grained pegmatitic variations which grade into massive quartz veins. Several such quartz occurrences outcrop along the road among the low hills just north and northeast of the Rockwell shaft, but none are large enough to be of any economic interest or to show any promising indications of metal contents.

The diabase is dark greenish gray and has a fine-grained ophitic texture, except along the dike margins and narrow offshoots, where it is black and dense. The visible minerals are white feldspar in short rodlike grains, in a soft dark-green chloritic material. There is a suggestion of porphyritic texture in places, a chloritized dark material (presumably augite) forming small phenocrysts. Microscopic study shows the feldspar to be principally plagioclase (An_{35}) accompanied by a little orthoclase. The composition of the former, more sodic than in the average diabase, and the presence of the latter are characters tending toward those of monzonite.

Both the topography and distribution of the quartzite and granite suggest faulting, especially around the valley just mentioned, but no faults were proved. The granite is thoroughly fissured in several directions, the principal systems trending north-south (dipping 45°–60° W.) and east-west (dipping 60°–65° N.). In both of these systems sheet jointing is very conspicuous. Another strong system has gentle dip and near the quartzite approximately parallels the intrusive contact.

ORE DEPOSITS.

The only known important ore deposit in Desert Mountain is the vein followed by the Rockwell inclined shaft, near the northwest end of the mountain, south of a group of low foothills. There are a few other prospects in the vicinity, but only a little work has been done on them. The vein follows a north-south sheeted fissure zone, which dips 60° W. The outcrop of copper-stained rock is 6 to 8 feet wide. It is partly covered by dump débris but is exposed for at least 50 feet south of the shaft, which begins in ore. The cliffs, however, on the spur just north of the shaft, although they

are cut by a strong north-south fissure zone in line with the vein, show no vein material. Any southern continuation of the vein is concealed beneath alluvium. The inclined shaft is said to be 235 feet deep and to follow the vein along its dip for almost the entire distance, but it was accessible to a depth of only about 100 feet. The width of the vein through this distance varies considerably. At one place the sheets of granite between close parallel fissures are impregnated and strongly stained with the blue silicate or green carbonate to a thickness of 3 to 4 feet; at another, mineralization is limited to a few streaks of the silicate or carbonate along the hanging wall of the fissure zone. At no place is replacement of the granite very pronounced, and the average copper content can not be much, if any, over 5 per cent. The bottom of the shaft cuts a diabase dike which is said to lie along the footwall of the vein. Fragments of this diabase on the dump are mineralized, proving the dike to be older than the vein.

The primary ore is chalcopyrite in large and small irregular grains partly altered to brownish-black iron oxide, accompanied by a little pyrite in small irregular grains. It occurs both in fissure fillings and in grains impregnating the granite and diabase. The gangue minerals are quartz and barite, which fill cavities and impregnate the wall rock for an inch or two, so that no sharp line can be drawn between vein and wall. The texture of the impregnated granite is preserved, but its feldspars and biotite are completely replaced by aggregates of microscopic sericite, quartz, and sulphides. Secondary minerals are brownish-black iron oxide, which marks the former presence of chalcopyrite in partly or wholly leached rock, and chrysocolla, which with malachite and secondary quartz fills veinlets cutting all the minerals of vein and wall alike, including the brownish-black iron oxide. The secondary quartz, either as minute glassy crystals or as chalcedony, continued to be deposited even after the copper silicate and carbonate.

The whole shaft is above water level, but the downward leaching of the ore is far from complete. Chalcopyrite can be found close to the surface, and considerable leaching, to judge from mineralized diabase fragments on the dump, has taken place at the bottom of the shaft. Chrysocolla and malachite are distributed all along the shaft and drift walls and show no special tendency to concentrate into bunches of high-grade ore.

Although the mineralized material is of high enough grade, especially if concentrated, to pay under more favorable circumstances, the long wagon haul, the railroad and smelter charges, and the lack of water prevent profitable working under present conditions.

SIMPSON MOUNTAINS (ERICKSON DISTRICT).

By G. F. Loughlin.

GENERAL FEATURES.

The Simpson Mountains, also known locally as the Judd Creek Mountains, are about 18 miles long from north to south and 2 to 6 miles wide and are bisected by latitude 40° N. and inclosed between longitude 112° 39′ and 112° 43′ W. They are separated by an alluvial valley on the east from the Sheeprock Mountains and by the old river bed on the west from the McDowell Mountains. (See fig. 48.) Their northern part is crossed through a pass by a stage road from Fausts to the Dugway Mountains; their middle part, including Indian Springs post office, is reached by a road, through the Sheeprock Mountains, from Vernon, or by a valley road from Fausts; and their southern part is most easily reached by road through the West Tintic Mountains from Eureka and other towns in the Tintic mining district. Each of these routes requires at least a day's travel on horseback or with a light rig.

A few springs in canyons along the lower slopes afford sites for camps. Simpson Spring, the northernmost, is on the west slope about 3 miles south of the north pass. A few prospects are located here, but none were reported active in 1912. Indian Springs, also on the west slope, in the long west-draining canyon of Indian Creek, which cuts the range nearly in the middle and is separated from the northeastward drainage by a low flat divide, furnish water for the O. K. Silver Mining Co., whose mine is the only one active at present, and for the irrigation of land. Sixmile Spring, about 4 miles south of Indian Springs, is the site of temporary prospectors' camps. Death and Blaine canyons on the south slope contain springs which supply water to a few prospectors and to ranging herds. Judd Creek, east of

these, supplies water for a ranch and, except in the driest seasons, flows far enough southward to afford a watering place on the road from Tintic. Desert Spring on the southeast slope is a similar watering place on the road to the Sheeprock Mountains and to Vernon. Limited growth of cottonwoods and other trees are grouped around several of the springs, but only stunted junipers ("cedars") and some mountain pine grow elsewhere. The junipers, however, are large enough to furnish mine timber for present developments.

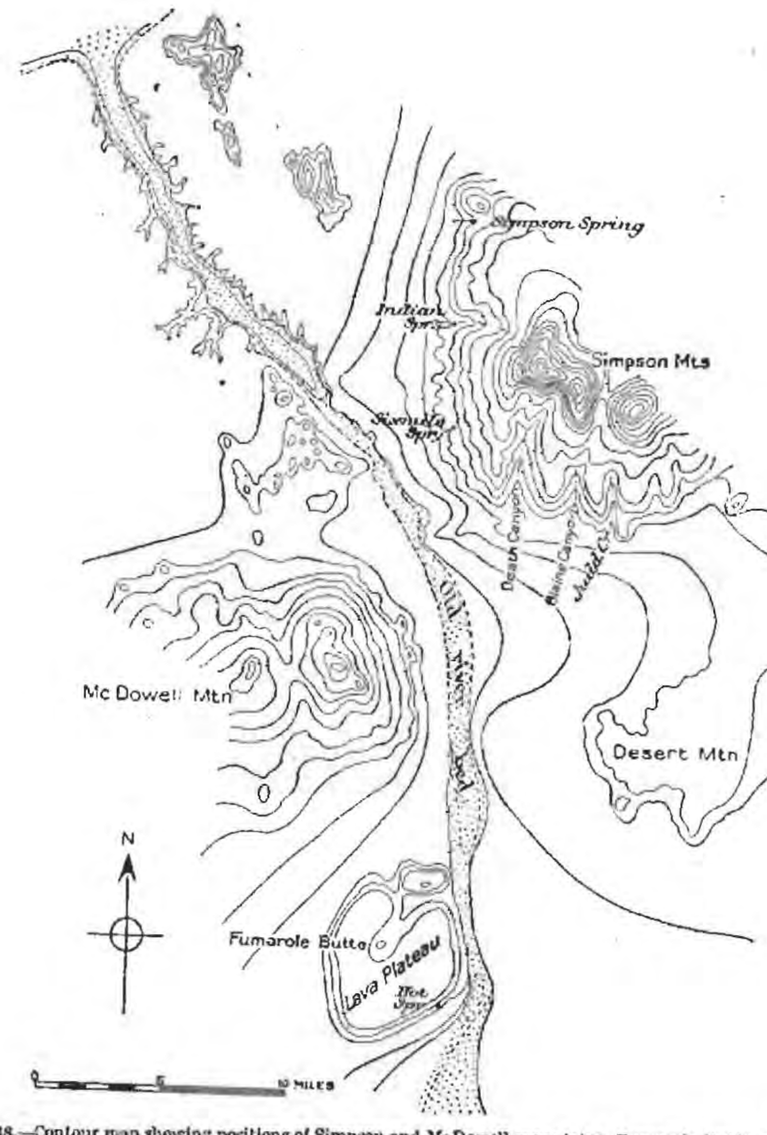

FIGURE 48.—Contour map showing positions of Simpson and McDowell mountains, Fumarole Butte, and Desert Mountain.

GEOLOGY.

The Simpson Mountains were studied only around Blaine and Death canyons and Indian Springs. The rocks here are mostly sedimentary but are cut by a few porphyry dikes and are covered in places by remnants of volcanic flows.

SEDIMENTARY ROCKS.

The sedimentary rocks may be divided into a lower series composed mostly of dark-weathering chloritic quartzite and shale and an upper series composed mostly of a lighter-weathering, nearly pure quartzite with a few intercalated beds of limestone, shale, and chloritic quartzite.

CHARACTER AND DISTRIBUTION.

The lower series makes up all the ridges from the southern base of the range as far as the divide that separates the southward drainages of Death and Blaine canyons from the north-

ward and westward drainage of Lee, Indian Creek, and other canyons. Its thickness is very great, amounting to some thousands of feet, but can not be accurately estimated until the faults are carefully mapped, as they obviously cause some repetition. The series is composed throughout of irregularly alternating beds of greenish shale, dark and light quartzite, and conglomerate; but green shale is most conspicuous on the lower southern spurs, especially at altitudes below Camp Blaine; green chloritic quartzite is most prominent for the next 800 to 1,000 feet above; a band containing considerable pure quartzite follows; and a considerable thickness of coarse conglomerate with thin alternating beds of shale and quartzite covers all. The shales throughout contain abundant mud cracks, and the quartzites are commonly ripple-marked and cross-bedded. These characters, together with the abrupt alterations between conglomerate and shale and an absence of fossils, indicate, although they do not prove, continental deposition.

The chloritic quartzite is greenish gray to dark purple, weathering to a brown. It is very fine grained and faintly banded. No minerals can be identified megascopically save minute sparkling specks of quartz. The rock consists of subangular grains of quartz and a few of plagioclase and mica in a feltlike matrix of sericite, chlorite, calcite, and secondary quartz. With increase of matrix and corresponding diminution in size of quartz grains the rock passes into shale. The conglomerate beds are composed almost wholly of quartz pebbles, including milky and smoky vein quartz, chalcedonic quartz, and occasionally quartzite, in a more or less argillaceous sandy matrix. Pebbles of granite, granite porphyry, and locally of gneiss are also common, though quite subordinate to the quartz. One conglomerate bed, containing, besides quartz, pebbles of fine-grained ferruginous sandstone cemented principally by more or less oxidized pyrite. is said to assay $2.60 in gold, which is probably contained in the pyrite cement of the ferruginous sandstone pebbles.

Near the summit of the southernmost peak east of Blaine Canyon and not far from the conglomerate horizon a dark calcareous shale bed is exposed; but no limestone, except a small isolated exposure of tremolite rock in the bed of a shallow south-sloping gulch west of the Happy Jack mine, is known to exist in the lower series. This rock is gray to greenish gray on fresh fracture but badly rust stained on weathered surfaces. Among the interlocking tremolite blades are the weathered remnants of pyrite cubes, mostly interstitial but a few included in tremolite. This rock is evidently the metamorphic equivalent of a limestone bed well down in the horizon of prevailing shale.

North of Death Canyon and along the divide into Lee Canyon the rocks differ markedly from those farther south. The peaks along the divide consist of a uniformly colored quartzite which appears to rest conformably upon the dark beds of the lower series. A short distance down Lee Canyon, along a local anticlinal flexure, a bed of dark-blue cherty dolomitic limestone is exposed within the quartzite. According to the strike and dip of the whole formation, this dolomitic bed should be expected to outcrop in the head of Death Canyon, but no such bed was found there, and it is tentatively concluded that the dolomitic bed is a lens or changes southward to a shaly member near the top of the lower series. West of Lee Canyon down Indian Springs Canyon, two or three other stratigraphically lower limestone beds that alternate with light and dark quartzite vary from light to dark and from finely granular to dense and shaly. They appear to change southward into shaly or quartzitic beds, but none of them was followed for any considerable distance along its strike. The lowest crosses the canyon just below the Indian Springs post office, where it overlies dark beds like those of the lower series. Detailed areal work may require a different interpretation. The light-colored quartzite which overlies the dolomitic bed in Lee Canyon appears to form all the peaks east of Lee Canyon and north of Indian Springs, but none of these peaks was ascended.

AGE AND CORRELATION.

Fossils collected by L. D. Burling in 1905 prove the limestone beds to be of Middle Cambrian age. According to the tentative interpretation that the limestones change southward into shaly members of the lower series, the upper part of that series is also Middle Cambrian and the lower part Lower Cambrian or earlier. The general similarity of the lower

series to the oldest rocks in the Sheeprock Range on the east also suggests very early Cambrian or pre-Cambrian age.

IGNEOUS ROCKS.

The igneous rocks include a few dikes or sills of granodiorite porphyry and monzonite porphyry and remnants of equivalent extrusive rocks. One diabase dike also was found.

GRANODIORITE PORPHYRY.

Five dikes (or sills), ranging in texture from granodiorite porphyry to dacite porphyry and locally called "quartz porphyry," were found. One of these, 65 feet in width, trends nearly south in a shallow southwest-sloping gulch just west of the low knoll by the Happy Jack mine. The dike was not traced for any considerable distance but is said to continue northward just west of the divide between Death and Blaine canyons for nearly a mile. The rock is light gray and very fine grained to dense porphyritic. The uniform white color of the altered feldspar phenocrysts and groundmass gives it a more granitic appearance than is really the case. The phenocrysts include altered plagioclase crystals up to 5 millimeters in length, quartz single grains and aggregates up to 4 millimeters in diameter, biotite, mostly faded, in 6-sided and irregular plates, and dark-greenish (altered?) hornblende in prisms 2 to 3 millimeters in length. The groundmass consists of irregular grains, 1 millimeter or less in diameter, chiefly of quartz and feldspars, but is much obscured by alteration to sericite, epidote, and chlorite. Owing to the alteration and to uncertainty as to ratio between plagioclase and alkalic feldspar it is impossible to classify the rock exactly. It is either a granodiorite or a quartz monzonite intrusive, but is distinctly more acidic than the monzonite described below.

A short distance northwest of the above occurrence, in a shallow south-sloping gully, a dike or sill of similar composition but finer texture outcrops. Of the other dikes of this group one 60 feet wide trends N. 20° E. across the east spur of the southernmost peak east of Blaine Canyon. A large dike outcrops with a N. 70° W. course on the east side of the Blaine Canyon road, about 1,500 feet southeast of the Happy Jack tunnel. A small dike was found farther south in the wash of the gulch just west of the knob at the mouth of Blaine Canyon, but its trend could not be determined. A small dike was also found at a small prospect on the west side of the Death Canyon road near the Utonia lower tunnel.

MONZONITE PORPHYRY.

The monzonite porphyry is medium to dark gray and very fine grained porphyritic. The phenocrysts include plagioclase (An_{40-45}), biotite, hornblende, and a few quartz grains. Small pyrite grains are also present. Some small dark patches or segregations evidently owe their darker color to a general lack of phenocrysts. The groundmass consists of small but fairly well formed laths of plagioclase and hornblende, virtually the smallest of the phenocrysts, embedded in a matrix of alkalic feldspar and quartz with little or no biotite. Microscopic quartz amounts to about 10 per cent of the rock.

In mineral composition the monzonite closely resembles the granodiorite, differing from it pronouncedly only by its greater abundance of black minerals and its corresponding lack of quartz. The plagioclase feldspars in the monzonite are somewhat less sodic than those in the granodiorite. The two rocks evidently had a common source, but it is not known which type was erupted first.

DIABASE.

The one diabase dike found outcrops on the west slope of the ridge west of Death Canyon, at its south end, and at about the same elevation as the Good Hope and the Last Hope No. 3 tunnels. The dike trends about north and south through dark quartzite and shale but is not well exposed for any considerable distance. It is dark gray on fresh fractures but weathers dark brown—about the same color as the weathered quartzite around it. It has the typical fine-grained ophitic texture, interrupted by a few small round feldspathic spots less than half an inch in diameter. The visible minerals are plagioclase (An_{65}), biotite, and a dull indeterminable material which the microscope proves to be altered augite. A little microscopic alkalic feldspar may be present in the interstices between plagioclase crystals, and small aggregates of serpentine represent the former presence of olivine. A little hornblende is also present. Calcite, the most conspicuous alteration product other than serpen-

tine, is accompanied by sericite and, in a veinlet, is intergrown with alunite. A little chlorite and epidote are also present. The abundance of biotite, the optical character of the augite, and the presence of brown hornblende give the rock a distinct resemblance in character to the latites and andesites in the Tintic and other districts of Utah, and it therefore seems probable that the diabase as well as the granodiorite and monzonite porphyries belongs to the great series of Tertiary igneous rocks.

EXTRUSIVE ROCKS.

Remnants of lava flows were noted at the low divide between Indian Springs and Lee canyons, and on the low hills on the north side of Indian Creek just west of the Indian Chief shafts. The one on the divide includes tuffs and flows of andesitic or latitic composition. The other is a dense rhyolite with phenocrysts of quartz and sanidine (glassy orthoclase) and weathered remnants of plagioclase and a very small amount of black minerals. Small fragments of obsidian (black volcanic glass) have been picked up at several places on the slopes.

These surface flows are found only in valleys and on lower hills, proving that the eruptions took place when the topography was much as it is to-day. How far they extend is not known, but probably similar remnants occur in some of the broader valleys and on the lower ridges flanking the range.

STRUCTURE.

The structure in the part of the range near Blaine and Death canyons and Indian Springs is for the most part homoclinal, the strata striking northwest and dipping 30°-35° NE. At the south end of the ridge west of Death Canyon is a gentle anticlinal flexure with northerly pitch, which dies out northward, and just north of the divide between Death and Lee canyons is a similar flexure. These are the only exceptions noted to the general northeastward dip.

The principal structural features of the area are fissuring and faulting. The most prominent fissures trend parallel to the bedding, north to N. 15° W. and N. 65°-85° W. Other faults and fissures trend N. 70°-80° E., N. 40°-50° E., N. 20° E., and N. 45° W.

Most of the fissures parallel to the bedding are strongly slickensided and may mark faults of considerable displacement, though the extent of displacement along any particular bed has not been found. Several bedded fissures are mineralized.

Fissures striking north to N. 15° W. (nearly parallel to the strike of the rocks) include both barren and mineralized fissures. The barren fissures are strongly slickensided and accompanied by faulting. At a small prospect on the southern peak east of Camp Blaine (fig. 49) a fault of steep westward dip that cuts off a dark calcareous shale bed is itself cut off by a fault along the bedding. Another fault, a reverse one with strike N. 5°-10° W. and dip 42° W., is exposed for a considerable distance along the Blaine lower tunnel. It finally flattens rather abruptly and its upper end merges with a bedding plane that dips gently eastward (fig. 50). The mineralized fissures of the system that trends north to N. 15° W. can not be followed on the surface for any considerable distance.

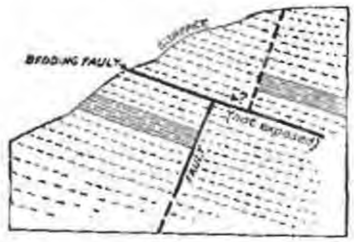

FIGURE 49.—Fault of steep westward dip cut off by a bedding fault at a small prospect on the southern peak east of Camp Blaine, Simpson Mountains.

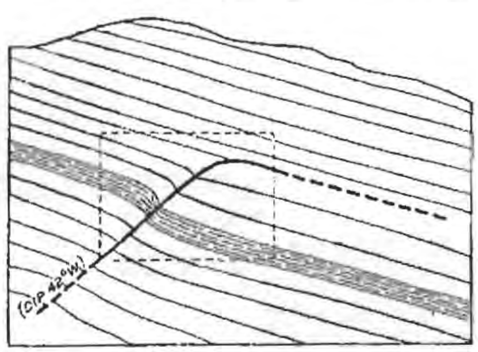

FIGURE 50.—Reverse fault exposed in Blaine lower tunnel, Camp Blaine, Simpson Mountains. Part exposed at different places along tunnel inclosed in dotted square.

Fissures that strike N. 65°-85° W. and dip steeply north are the most persistent of any found but are relatively short compared to the strong fissures of the larger mining districts. Most but not all of them are mineralized. The

most persistent of this system are the main fissures in the upper Blaine tunnel and in the Silver Reef tunnels, the Blaine fissure having been followed for at least 400 and the Silver Reef fissure (in the lower tunnel) for over 500 feet. Other fissures of the same system—for example, the West End fissure of the Blaine and the principal fissure of the Happy Jack workings—have not proved continuous either horizontally or vertically, but after a short distance branch into a number of fractures and disappear within a few feet. It is probable that where such a fissure ends a second parallel fissure begins near by and virtually continues the first; but the finding of the continuation is a matter of chance. Mineralized branch fissures trending in different directions are connected with these main fissures. The strikes of those noted are N. 80° E., N. 70° E., N. 50° E., and N. 45° W. The dips where measured are southerly.

The only other fissure worthy of mention is a N. 40° E. fault fissure, with small displacement, seen on the ridge east of Blaine Canyon. Besides these fissures, others in various directions are associated with rock shattering and accessory to the stronger fissures, as in the Happy Jack tunnel.

The dikes lie mostly parallel to the north to N. 15° W. and the N. 65°-85° W. fissure systems; but one, which outcrops on the east spur of the southern peak east of Blaine Canyon, is 60 feet thick and trends N. 20° E.

The critical feature of the fissures is their lack of continuity. Some of them, including those parallel to the bedding and the barren faults noted in the system that strikes north to N. 15° W., appear to have been formed during the period of compression which produced the anticlinal flexures. This force was evidently insufficient to produce intense folding in the district, though capable of shearing the rocks and producing local compression faults. Owing to the unequal resistance of the different strata, clean-cut fissures were developed in the more quartzitic beds but failed to persist in the more shaly beds; the broken quartzitic masses, or blocks, could thus yield by fault movement and be squeezed against or even into the yielding shale beds, producing the complications of bedding shown in the Happy Jack tunnel. The sliding of block upon block would take place not only across but along the bedding, with the result that although the total displacement is considerable, the movement along any one fissure, or fault plane, is small. The fissures would form a network, but no single fissure would necessarily persist for any considerable distance.

After the close of this period of compression more fissuring took place, the more persistent fissures evidently affording channels for the dikes. Further fissuring probably took place after the dike intrusions, but no definite data on this point are at hand, except that the dikes have undergone the same kind of alteration as that shown by the sedimentary rocks along the mineralized fissures.

The presence of older fissures as well as the uneven rigidity of the sedimentary rocks would both tend to interrupt the continuity of later fissures. Where the disrupting force was strongest, it may have been sufficient to produce a fissure that persisted through the thinner shale beds and was only slightly interrupted where crossing older fissures, but that broke up on entering weaker or thicker flexible shaly beds and formed two or more fissures approximately but not quite in line. A new fissure, especially where the disrupting force is relatively weak, on approaching an older fissure is likely to be deflected toward the older fissure. The rock beyond the older fissure may or may not be cut by another new fissure, and the new fissures on opposite sides of the old are not likely to be in line. The rock at the junction of fissures may be considerably shattered. The disrupting force, furthermore, may not, for one reason or another, be of uniform intensity and fissures may branch and die out even where the rock is reasonably uniform. Too little work has been done to compare the relative influence of these different conditions in the Simpson Mountains, but all have evidently been operative in producing the complex network of fissures. (See fig. 51.)

ORE DEPOSITS.

GENERAL FEATURES.

OCCURRENCE AND CHARACTER.

The ore deposits of the Simpson Mountains lie within the Erickson mining district, which includes all the Simpson Mountains and also the western slopes of the Sheeprock Mountains as far north as Government Creek. Nearly all

the deposits are in vein form, but some replacement bodies occur at Indian Springs. Many small outcrops, or "blowouts," of mineral veins are scattered over the surface of the Simpson Mountains, but few of them are traceable for considerable distances, partly because they are hidden by float and talus and partly because they are not persistent. A few veins are distinct for horizontal distances of 300 to 500 feet and have local bunches or shoots of pay ore, and some ore bodies occur as small isolated bunches with

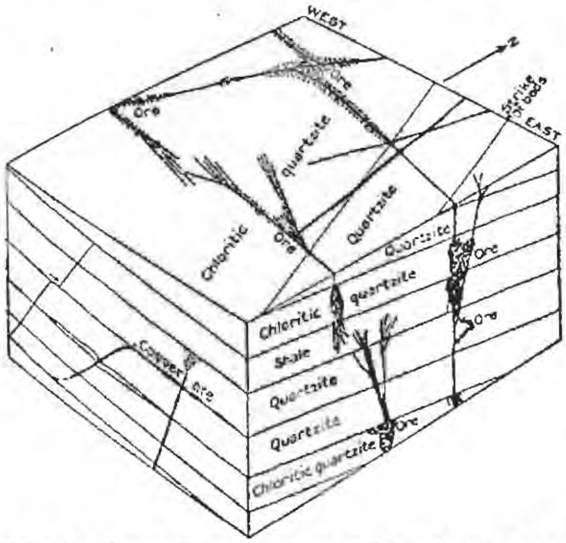

FIGURE 51.—Diagram showing relations of different fissures to one another, also relation of ore shoots to fissuring and composition of wall rock in southern part of Simpson Mountains.

no apparent connection other than inconspicuous barren fissures.

The veins may be divided into two groups—those parallel to the bedding and those filling nearly vertical fissures.

BED DEPOSITS.

Deposits parallel to the bedding are composed chiefly of white milky quartz with some small bunches of chlorite, scattered lumps of chalcopyrite, some of which are 2 inches in diameter, and a few small aggregates of specular hematite. These deposits are mostly lenticular but range from a succession of short detached lenses along the same bedding plane to a relatively continuous deposit with local lenticular bulges. The average thickness of the bulges is about 5 or 6 inches, and the maximum thickness seen was about 1 foot. One or both of the walls as a rule is light colored relatively pure quartzite. Where chloritic quartzite or shale forms one wall, chlorite is likely to be conspicuous. The chalcopyrite lumps are more or less altered to bornite, chalcocite, malachite, azurite, and chrysocolla. Under the microscope the chalcopyrite is full of irregular granules of pyrite. A few grains of galena have been found.

The amount of ore in these quartz-chalcopyrite deposits is insignificant, except in the Highland Lassie No. 1 prospect at Sixmile Spring (p. 456), which is also exceptional in the position of the vein. The workings were not accessible when visited, but the ore body is said to be small, though rich, and to cut across the bedding, pinching out a short distance below the surface. A very little barite was found with this ore.

FISSURE DEPOSITS.

The veins filling nearly vertical fissures vary considerably in composition. Those seen at Indian Springs are composed of quartz with a minor amount of calcite and a varying amount of very fine pyrite grains. A few grains of chalcopyrite were also noted. The quartz fills cavities developing typical comb structure and also replaces the calcareous wall rock. The calcite is mostly a later growth filling fractures in the quartz and also in places filling the central portions of cavities or pockets. The pyrite is found along the edges of cavities and scattered among the microscopic quartz grains. This pyritic quartz-calcite ore is said to contain gold to the amount of $7 to $12 per ton, but where pyrite is locally concentrated into visible streaks or patches of fine grains, the amount is considerably larger. The small amount of chalcopyrite holds the same relations to the gangue as does the pyrite but occurs in larger grains.

The veins at one horizon on the O. K.-Silver Reef property merge with a strong deposit of vein and replacement quartz which follows the bedding for a considerable distance. The original bed was probably a limestone, but replacement has been so complete that no remnants of the former rock could be found. The nearest exposed beds above and below it look like shaly limestone but are siliceous and yield no effervescence when touched with hydrochloric acid. The oxidized ore in this replacement body contains sulphantimonites of silver and horn silver, and shipments made early in 1916 are reported to have yielded 400 to 500 ounces

of silver and 0.02 to 0.235 ounce of gold to the ton.[1] Silver in valuable amounts has been found at only two places—the O. K. incline and the Silver Reef open cut.

The veins of lead-zinc ore around Blaine and Death canyons also contain quartz, but it is less conspicuous and in many places is subordinate to calcite and chlorite. The metallic minerals are galena, zinc blende, pyrite, and locally chalcopyrite. Both the gangue and ore minerals vary in quantity, and each predominates locally, but as a whole calcite is perhaps the most abundant gangue and galena and zinc blende the most abundant ore minerals. The width of these veins is very irregular, and ore shoots occur at intervals, evidently where chlorite beds and excessive shattering have produced favorable conditions. (See fig. 51.) Some veins, which are marked for considerable distances by a little impregnation of the walls by pyrite and by a few scattering crystals of galena and zinc blende, abruptly expand, on meeting a favorable chloritic bed, to 1 to 6 feet of ore. The chloritic beds were evidently readily subject to attack by the vein-forming solutions; and it is noteworthy that the gangue minerals here, quartz, calcite, and chlorite, are the same as those which constitute the rock. Sericite, which is prominent in the rock, is also a minor gangue mineral. The ratio of gangue minerals, however, is very variable and in most or all places is markedly different from that in the wall rock. Considerable transfer of material in solution must have taken place, the rock constituents being removed and the ore minerals depositing in their stead. Where conditions of deposition were most favorable, galena and blende in good-sized crystals or aggregates tended to concentrate in the central part of the shoot and pyrite to impregnate the surrounding walls; but in most shoots considerable pyrite in crystals, some of which are a quarter of an inch or more in diameter, are scattered through the ore. The pyrite in the rock around the margins of a shoot is commonly fine grained.

Fluorite was seen in one place, associated especially with leached quartz and lead carbonate, but the caving in of the workings prevented an adequate study of its occurrence. It is, however, of interest as a connecting link between the composition of the veins of the Simpson Mountains and those of the Sheeprock Mountains to the east.

Alunite, in microscopic flakes intergrown with calcite, was found in a veinlet cutting a diabase dike. This intergrowth is of particular interest as an indication that the alunite was deposited by an alkaline or neutral solution, for acidic solutions would have dissolved rather than deposited calcite. It supplements evidence in the Marysvale district (pp. 546–550) that alunite may be a primary constituent of veins deposited by ascending solutions as well as a secondary mineral deposited by acidic waters in the zone of oxidation. This occurrence is also of interest in showing the similarity between the Simpson Mountain veins and those of other ranges. The alunite, a hydrous potassium-aluminum sulphate, is confined to the veinlet, and the feldspar of the diabase is considerably altered to sericite, a hydrous potassium-aluminum silicate.

RELATIONS BETWEEN THE DIFFERENT VEINS.

Surface exposures and underground developments are too slight to show any definite transition or change in the contents of a single vein, but the different types of veins grade into one another in composition. Thus the quartz-pyrite veins and replacement bodies contain a little chalcopyrite and more or less calcite and may grade into the quartz-chalcopyrite veins and also into the veins rich in calcite. The quartz-chalcopyrite veins contain a small amount of galena, and as one of them at the Last Hope No. 3 prospect (p. 456) passes into a small body of rich galena ore, the connection between them and the calcite-lead-zinc veins is reasonably well established. At one prospect on the ridge west of the Blaine tunnels a vein composed of calcite, considerable quartz, galena, and oxidized copper minerals is clearly intermediate between the last two types mentioned. No definite relation as to relative depth of crystallization or distance from their source can be established until the area has been mapped and studied in detail.

OXIDATION.

The oxidation products or secondary minerals of the veins present no unusual features. Pyrite has oxidized to limonite, giving a typical limonite-stained quartz, which retains

[1] Mining Press, Feb. 5, p. 216, and Mar. 4, p. 355, 1916.

the gold originally in the pyrite. Chalcopyrite, as proved by microscopic study of polished surfaces, has altered to pitchy black to brown limonite, and all these minerals are cut by veinlets of the copper carbonates, malachite and azurite, and the silicate, chrysocolla. Galena has changed to the lead carbonate, cerusite (also called "crystallized lead" and "sand carbonates"), and remains in the veins above water level, but no conspicuous alteration product of zinc blende has yet been found, although zinc blende and galena occur together. The decomposition of zinc blende was accompanied by transfer of the zinc as sulphate away from its original position, and it is to be expected that, in the absence of limestone beds which oxidized zinc ore could replace, no concentration of oxidized zinc ore has taken place. Small amounts of calamine, the hydrous silicate, may be found, however, replacing chloritic quartzite or lining cavities.

A few bodies of the black manganese ore, chiefly pyrolusite and wad, are also found. One, on the south slope of the peak east of Blaine Canyon, has been prospected and found to replace a shaly bed between quartzite strata, but no definite connection between it and unoxidized material has been exposed. It consists of a few high-grade lumps or segregations in a soft brownish-black earthy material. Another outcrop of manganese ore is exposed near the south end of a low spur just southeast of Camp Blaine. The workings were not accessible, but it was said that the manganese ore was followed down an incline for 120 feet and that within 20 feet of the surface some lead-silver ore was found. There thus seems to be a close relation in origin between the lead and manganese ore. It is interesting in this connection to cite the work of Nishihara, who has shown that galena from several different places contains small amounts of manganese, probably as sulphide;[1] but in the Utonia workings, inaccessible in 1912, the black manganese ore changes abruptly to rhodonite, the manganese silicate, at water level, 100 feet below the surface. This deposit and others in the Tintic and Erickson districts were studied by J. T. Pardee in 1918, when manganese ore was being shipped from the Black Jack group and development work was being conducted on several other claims in the vicinity.[2]

MINES.

BLAINE MINE.

The Blaine mine, owned by the Blaine Gold & Silver Mining Co., in Blaine Canyon, on the southern slope of the Simpson Mountains, was worked in the eighties, when 100 tons of sandy lead carbonate ore, mined from the shaft, was shipped to the old smelter at the Hot Springs north of Abraham. The workings in a spur on the west side of the canyon include the old shaft, a short tunnel called the West End, and an upper and lower tunnel. The country rock, a dark-weathering impure quartzite, includes several intercalated green massive to shaly beds containing abundant chlorite, sericite, and calcite.

The upper Blaine tunnel, which lies at the approximate boundary between oxidized and unoxidized ore, follows a fissure with N. 65°–70° W. strike and 75° N. dip, whose walls are sprinkled with fine pyrite and some galena and blende. At 255 feet from the entrance the ore forms a vein 12 to 22 inches thick (average 14 inches). It has been followed down the fissure in a winze for 30 feet or more and upward in a 40-foot raise, in which its width is 10 to 12 inches, with some pinches. The ore in the winze comprises blende, galena, and pyrite, with some lead carbonate and oxides of iron and manganese. A 12-ton sample taken 30 feet below the tunnel level ran 51 per cent zinc, 13 per cent lead, and 4 ounces of silver and 0.021 ounce of gold per ton. The ore in the raise is chiefly lead carbonate, with some galena, and averages 25 per cent lead (no zinc reported). Farther west, at the second crosscut, the vein swells to a width of 5 to 6 feet. The fissure beyond this place leaves the south wall of the drift but is cut by a south crosscut toward the shaft, where both of its walls are impregnated with fine galena. Eight feet south of this fissure another, striking N. 70° E. and converging eastward with it, is accompanied by the usual ore in a greenish gangue and locally by blende and galena in a white gangue composed chiefly of calcite. Two

[1] Nishihara, G. S., The rate of reduction of acidity of descending waters by certain ore and gangue minerals and its bearing upon secondary sulphide enrichment: Econ. Geology, vol. 9, pp. 743–757, 1914.

[2] Manganese ore in Tintic district, Utah: U. S. Geol. Survey Press Bull. 379, pp. 3–4, September, 1918.

other parallel or slightly converging veins with chloritic ore have been cut by the second crosscut to the north. The northern of these two, which lies in an east-west fissure zone accompanied by some faulting, has been flolowed for a short distance and is said to have contained some fluorite in the gangue, but none was seen during the writer's visit. A barren white quartz vein along the bedding is cut off by a fault just south of this northern vein.

The lower Blaine tunnel extends 740 feet nearly due north. About 400 feet from its mouth it crosses a few white quartz veinlets 1 to 3 inches thick which carry a little pyrite, chalcopyrite, and a few grains of galena. From this point northward it follows for a considerable distance a reverse fault of small displacement, which trends N. 10° W. and dips 42° W., along which are many east-west fractures. The north-south fissure finally flattens and merges with a bedding plane beneath a massive quartzite stratum. Seven hundred feet from the tunnel mouth, short east and west crosscuts have been run along a fault fissure that strikes N. 70° W. and dips about 70° N., and that may be the same as that followed by the upper tunnel. The hanging wall is shattered chloritic quartzite thoroughly impregnated with fine grains of pyrite and coarse grains and aggregates of blende and galena and crisscrossed by veinlets of white calcite. The ore body just east of the tunnel is about 8 feet wide, and lies in the wedge between the main fissure and a branch northwest-southeast fissure with southwest dip, which crosses the tunnel 12 feet north of the main fissure. West of the tunnel the main fissure branches and the ore disappears from the crosscut along a north-northwest branch fissure. Assays of samples from the lower tunnel have shown 24 per cent lead and 3½ ounces of silver per ton. No assay for zinc was made.

The West End tunnel and winze west of the shaft follow a nearly vertical north-dipping east-west fissure, which yielded oxidized lead-silver ore. The ore gave out where the fissure appears to feather out downward, and no prospecting has been yet attempted to hunt for any continuation of it. The shaft also follows a steep north-dipping fissure which may be in the same zone as the main fissures exposed in the upper and lower Blaine tunnels.

The ore bodies thus far exposed in the Blaine workings lie where fissures that strike N. 65°–80° W. and dip 70°–80° N. cut the more chloritic beds, and the largest exposures appear to be where these beds are shattered and the fissures branch. The ore in places extends a short distance from the fissure along bedding planes, replacing or impregnating the chloritic rock. The ore is not continuous along the fissures but lies in small shoots between lean or barren stretches, in which the fissure crosses beds of purer quartzite or crosses more favorable chloritic beds but is not markedly shattered.

HAPPY JACK PROSPECT.

The Happy Jack prospect, under the same control as the Blaine mine, is on the west side of Blaine Canyon, about half a mile south of the Blaine lower tunnel. The workings, which are all above water level, include a shallow inclined shaft and short drift, both of which follow the mineralized fissure zone, and a sinuous northwest tunnel about 250 feet long, which connects with the bottom of the shaft 10 feet below the short drift.

The country rock is impure quartzite and shale in irregularly alternating beds, which dip easterly. The dip varies greatly within short distances from horizontal to vertical. The beds are much fractured in various directions and greatly disturbed by local faulting and crushing. In one place a hard quartzitic block has been squeezed against soft chloritic rock, crushing it to a soft gouge which tends to surround the slickensided quartzite block. The crushed material that is exposed is barren, and the only ore of any consequence lies along an east-west fissure zone with an average dip of 80° S. that persists from the surface down to the tunnel level, where it shows some signs of pinching out downward. The ore exposed in 1912 was all sandy lead carbonate. It forms bunches where the fissure zone crosses the more chloritic beds The ore in the shaft thinned out downward, but the short level west of the shaft has opened another body which extends about 15 feet across the strike of the fissure zone but has not yet been followed along the fissure. The fissure where cut on the tunnel level is not mineralized and attempts to find a downward continuation of the ore have not succeeded. The only ore found on the tunnel level is close to the face and comprises three or

four small bunches of sandy lead carbonate with kaolin and iron and manganese oxides. This material forms thin connected lenses with central bunches of $PbCO_3$ that follow a flat-dipping bedding plane for about 20 feet and cross through a short cross fracture to a bedding plane 2 feet higher. These lenses are possibly offshoots from the main fissure, which should lie a little north of the tunnel face. No ore has been shipped.

O. K. MINE.

The O. K. mine, owned by the O. K. Silver Mining & Milling Co., lies well up the south slope of Indian Springs Canyon above the camp and post office. The country rock includes a bed of dark calcareous rock that dips 32° E. between belts of light quartzite. The ore body lies parallel to the bedding and is a replacement of the basal member of the calcareous belt. The principal mining has been along an incline from the outcrop down the dip, and the ore extracted is said to have been largely silver sulphantimonides and horn silver in a quartzose gangue, the best values lying along the bottom of the incline. At the base of the incline a short drift leads to a series of caves lined with stalactites and stalagmites. The bottom of one of these caves is also said to have contained ore of unspecified character.

SILVER REEF MINE.

The Silver Reef mine, owned by the O. K. Silver Mining & Milling Co., is on the north side of the canyon, opposite Indian Springs post office. In 1912 it was opened by two tunnels, a shaft, and a small open cut. The country rock is mostly light to dark brown weathering quartzite, with a few bands of shale and three or four of limestone or dolomite. The beds dip 30° to 35° NE. The mineralized fissures strike west-northwestward. The workings include two tunnels, a shaft, and a small open cut.

The lower tunnel follows a narrow fissure vein in dark impure limestone. Between 500 and 600 feet from the tunnel mouth the vein material is a crushed black silicified limestone 5 to 6 feet wide, filled with quartz, calcite, and fine-grained pyrite, lying between two parallel slickensided fissures. On the south side of the crushed zone are 6 feet of barren wall rock, then a second quartzose crushed zone vein with a dip of 50° N., which may join with the first crushed zone below the tunnel level. The ore in the crushed zones is said to average $7 to $12 a ton.

The upper tunnel also follows a crushed zone vein, either the same as that in the lower tunnel or one closely parallel. The ore is of the same type as that in the lower tunnel but is said to have yielded higher returns. Specimens said to represent the richer gold ore are evidently local concentrations of fine pyrite with an inconspicuous quartz gangue.

The shaft goes down about 40 feet in rusted quartz, in line with the upper tunnel vein, and connects with two short drifts, one east-southeast along the vein and one southwest along a branch vein. Ore from these workings consists of quartz and limonite containing silver and a little gold.

The ground around the shaft shows only quartz in short reticulate veinlets with marked comb structure and innumerable small pockets surrounding fragments of silicified rock. The quartz outcrop is 30 to 40 feet wide and can be traced for a short distance south of the shaft and northward beyond the limits of the property. The small open cut, just opened at the time of the writer's visit, has exposed some oxidized material said to yield very high values in silver. The exact source of the silver could not be found at the time, as the only recognizable primary mineral found was a little chalcopyrite. Specimens sent to the writer in 1916, probably from a newly opened ore body 60 feet below the surface, contain sulphantimonides and chloride of silver in a gangue of rusted pyritic quartz. Both silver minerals are secondary. A shipment from this body yielded 488 ounces of silver and 0.235 ounce of gold to the ton, and 0.15 per cent copper, and another yielded 405 ounces of silver and 0.02 ounce of gold to the ton.[1] The ore is hauled to a loading point near Tintic Junction on the Los Angeles & Salt Lake Railroad.

INDIAN CHIEF PROSPECT.

The Indian Chief, formerly called the Yellow Jacket, property adjoins the Silver Reef on the west. The workings include three inclined shafts. Only one of these shafts was accessible at the time of the writer's visit, and the

[1] Min. and Sci. Press, vol. 112, pp. 216, 855, 1916.

bottom of this was filled with water which stood 95 feet below the shaft collar. The three shafts lie on or close to a fault fissure which strikes N. 70° W. and dips 65° N. The amount or direction of displacement is not known. The immediate country rock is a gray dolomitic limestone which overlies or lies within black dense argillaceous limestone. The footwall of the fault consists of gray dolomitic rock for a few feet from the surface and of black limestone for the rest of the way to the bottom of the workings. The hanging wall consists entirely of black dense limestone criss-crossed by barren calcite veinlets. Small bunches of lead carbonate and galena ore were found at the surface in two of the shafts but did not persist downward and were evidently confined to the gray dolomitic rock. Some of the ore fragments on the dump had quartz gangue; others had no conspicuous amount of quartz. The sorted ore is said to have run 60 to 70 per cent lead and 8 to 14 ounces of silver to the ton. The third shaft was sunk in a copper-stained limonite body, but no relation of this material to the country rock or to the lead ore could be determined, owing to the surface coverings of débris. The quartz body, which passes north-northwestward from the Silver Reef shaft, traverses the Indian Chief property, but there it shows no promising samples.

UTONIA TUNNELS.

The Utonia tunnels are in the middle part of the west slope of Death Canyon. They are four in all, but none was being worked when visited. All are in the lower impure quartzite, and all are said to have struck water. Only the lowest was entered. This tunnel penetrates to a fissure vein that strikes east and dips steeply north and carries galena, blende, and cerusite (lead carbonate). A watercourse follows the vein. It is reported that two carloads of lead-zinc ore were shipped in the nineties, but their value is not known. Similar ore is said to occur in the other tunnels. Black manganese ore derived from rhodonite has already been mentioned (p. 453).

GOOD HOPE PROSPECT.

The Good Hope lead-silver prospect, worked by B. F. Fleiner and others, is located on the southeast slope at the end of the ridge and is reached by trail from Death Canyon. A short drift follows a N. 3° W. fissure, dipping 68° W., for about 20 feet along its intersection with a chloritic stratum which lies between two hard quartzite beds. The ore, galena and cerusite, now largely leached, is represented by a spongy gossan held together by a fine network of quartz, chiefly as a replacement of the chloritic bed. Some fragments of fluorite lining vugs in quartzite were found on the dump.

LAST HOPE PROSPECT No. 3.

The Last Hope No. 3 tunnel, worked by Swen Nelson, is on the west slope of the ridge, above and directly east of Sixmile Spring. The tunnel follows a thin seam of vein quartz eastward along a nearly horizontal bedding plane in impure quartzite. The quartz contains a few small pockets lined with crystals, more or less oxidized chalcopyrite in irregular lumps, some of which are 2 inches in diameter, and small scattered crystals of galena. About 50 feet from the tunnel mouth the bedded quartz vein connected with a vertical east-west lens-shaped body of coarse-grained galena 2 to 3 feet thick, 5 to 6 feet high, and 10 feet or more long, with warped cleavage surfaces almost totally free from gangue. Some ore still remains in its eastern face. The walls around the galena body were so decomposed that no relations with fissuring or wall rock could be determined. The tunnel continues for some distance beyond the galena body, but no more ore has been uncovered. A few other bedded quartz veins 6 inches or less thick outcrop a short distance above the tunnel mouth but have not yet been prospected.

HIGHLAND LASSIE PROSPECT No. 1.

The Highland Lassie No. 1 is on the slope just north of Sixmile Spring. The workings are now caved, but a small pile of copper ore remains on the dump. The ore is chalcopyrite, mostly altered to pitchy black and brown limonite, malachite, and chrysocolla, accompanied by only a little fine-grained vein quartz. It replaces rather pure quartzite. The malachite and chrysocolla fill cracks traversing the other minerals. The vein quartz is not easily distinguished from the quartzite wall rock. In fact it may be simply recrystallized quartzite mixed with the replacing copper minerals. The ore is said to have followed a short fissure which for a short distance dipped steeply west,

normal to the dip of the quartzite, then changed to a steep easterly dip and pinched out. Assays of the copper ore are said to have yielded very good returns of silver.

FUTURE OF THE DISTRICT.

Without doubt mineralization around Indian and Sixmile springs and Blaine and Death canyons extends over a wide area, but ore as a rule appears to be confined to small disconnected bodies. This condition is due to the variation in character of the country rock, the scarcity of persistent fissures, and the character of the solutions that deposited the ore. The solutions were evidently not able to effect any conspicuous replacement of the pure quartzite, and fissures in that rock were not continuous or open enough to permit the deposition of ore minerals in commercial quantity. Where the solutions, percolating through the network of fissures, came in contact with the green chloritic beds, they produced some replacement, the extent of which varied with the amount of chlorite and calcite in the rock and the presence of branch fissures or local shattering which would allow a more thorough permeation. The size of an ore shoot is thus limited to the thickness of certain replaceable beds, and may further be limited in any direction by the local pinching out of a fissure. Large ore bodies therefore are not to be expected, but small bodies of good ore are known to be present.

The high-water level is unfavorable. Soft oxidized ore, chiefly lead carbonate in which the silver content may be relatively high, is limited by it to the uppermost part of a deposit and passes downward to a mixed sulphide ore composed chiefly of galena, zinc blende, and pyrite, the mining of which involves the removal of water. This water may, of course, under some circumstances, be used for irrigation.

The most serious obstacle is the lack of rail transportation. Ore must be hauled by wagon about 40 miles to the Los Angeles & Salt Lake Railroad.

Even under these adverse conditions, the assay results from several prospects would be promising if they represent average samples and not picked specimens, as many of them do. Present conditions seem to warrant mining with small forces of men and without expensive equipment, so that the abrupt pinching out of a body shall cause the least possible loss of capital; they also warrant systematic prospecting in connection with present work. Success in such prospecting will depend largely on a knowledge of the positions of replaceable chloritic quartzite and limestone beds and of the direction and distribution of mineralized fissures.

A great many small ore bodies doubtless exist, and the problem is to find them with as little dead work as possible. The limestone beds around Indian Springs might be expected to contain the largest bed replacements, but no promising evidence of mineralization has been found in any except those in the O. K. and Silver Reef workings.

FUMAROLE BUTTE AND LAVA PLATEAU.

By G. F. Loughlin.

Fumarole Butte, locally known as "The Crater," and the surrounding lava plateau lie just within the southern boundary of Juab County, about 12 miles north of Abraham and 19 miles west of Lynn Junction on the Los Angeles & Salt Lake Railroad. The Lava Plateau is bounded on the east by the old river bed. (See fig. 48, p. 446.) The butte and plateau form a denuded volcano composed of basaltic lava, which was erupted in Tertiary time after the upheaval of the surrounding Basin Ranges and was subjected to considerable erosion before the Lake Bonneville epoch of Quaternary time.[1] The butte, which is about 160 feet high, is a denuded volcanic neck of dense basalt, and is surrounded by a depression attributed to the relatively rapid erosion of the cinder cone. Moist air at a temperature of 62°–73° F. issues from thirty or forty crevices in it. The plateau is made up of successive flows of vesicular basalt and is about 5 miles in diameter. It is bounded by low cliffs, attributed to the collapse of the hard basalt when undermined by the erosion of underlying cinder or tuff beds. The edges of the plateau are cut by several short valleys; also by one principal valley which heads at the volcanic neck and extends northeastward for some distance along a possible fault, and then turns sharply along an undoubted fault to the old river bed. The por-

[1] Gilbert, G. K., Lake Bonneville: U. S. Geol. Survey Mon. 1, pp. 332-335, 1890.

tion of the plateau north of the valley is marked by two minor wave-cut terraces which converge northward, one sloping 3° N. and the other 1½° S., which indicate that faulting, with northward tilting of the northern block, continued during the existence of Lake Bonneville. The valley contains deposits laid down during both the older and later stages of the lake. The age of the fault and of the erosion along it can thus be fixed within reasonably close limits—distinctly later than the upheaval of the Basin Ranges and earlier than the existence of Lake Bonneville; with some faulting continuous during the earlier stages of the lake. The faults, though part of the great system of Great Basin faults, are distinctly younger than the mineralized faults and fissures in the neighboring mountain ranges, as evidence shows that mineralization in them took place before the upheaval of the ranges.

A marshy area on the flat between the southeast edge of the plateau and the old river bed contains a number of low mounds from which hot springs issue, probably from a buried fault extending along the southeast or east side of the plateau.

Temperatures of the springs ranging from 110° to 178° F. were recorded by Gilbert. It is said that up to 1901 or 1902 one of the springs used to spout in geyser fashion and that the water rose 10 feet in the air. Red, yellow, green, and white slimy algous deposits containing carbonates of calcium, iron, and a little magnesia, and a little silica and gypsum are accumulating in streams that flow from the springs. A partial analysis of a considerable deposit of hardened red material that forms a low mound around an extinct spring vent shows that it consists chiefly of calcium carbonate, with 4.47 per cent total iron as Fe_2O_3, a very little silica, and traces of alumina and magnesia. The thickness of this mass or of the marshy growth around the springs is not known, but it is doubtless very slight, the material resting upon the old lake beds. The water from the springs is strongly saline; a field test made by O. E. Meinzer, of the United States Geological Survey, showed it to contain about 1,600 parts per million of chlorine.[1]

In the eighties a small smelter was erected at the Hot Springs with the intention of treating ores from surrounding districts, and an attempt made to use the "iron ore" around the extinct spring vent for a flux. Only a very small amount of the spring deposit was mined, and the venture was not successful. The exact causes of the failure are not known, but the low percentage of iron quoted above may be one cause.

[1] Meinzer, O. E., U. S. Geol. Survey Water-Supply Paper 277, p. 103, 1911.

DUGWAY-GRANITE RANGE.

By B. S. Butler.

GEOGRAPHY.

The Dugway-Granite Range is somewhat irregular and has been given different names in different portions of its length.[2] Its north part is known as the Granite Range; that farther south, beyond a low pass, as the Dugway Range; that south of the Dugway road as the Thomas Range; that still farther south, in the latitude of the Detroit mining district, as the Drum Mountains; and that at the extreme south as the Little Drum Mountains. Mining operations have been carried on in the Detroit district, in the Dugway district, and in the Granite Range.

The Dugway Range is more irregular than the House and Fish Springs ranges to the west, being composed of several rather indefinite ridges trending slightly west of north, although the range as a whole trends nearly north. In but few places does it attain an elevation of 7,000 feet, and it contains numerous broad open valleys.

Water is scarce and usually is not of the best quality. Only a very little irrigation is possible, and all farm produce must be brought from other districts. In the Detroit district at Joy a tunnel in the volcanic rocks furnishes a small flow of water, and a well supplies water to ore freighters. Wildhorse Spring in the Thomas Range furnishes a small supply of water. The Dugway district contains no permanent water supply, but several cisterns have been constructed in which small supplies can be stored. The Granite Range, on the other hand, contains several springs, and supplies could doubtless be developed in many of its canyons.

Wood is scarce, and there is none suitable for mine timber or for building purposes.

The nearest railroad point for the Granite and Dugway districts previous to 1917 was St. Johns, about 50 miles distant. In 1917 a

[2] U. S. Geol. Survey topographic map of Fish Springs quadrangle.

railroad was completed from Wendover to Gold Hill, 30 to 40 miles from the different sections in the northern part of the range. The Detroit district is about 30 miles from Oasis. Transportation costs are therefore high for all the districts of the range.

PHYSIOGRAPHY.

The general physiography of the Granite-Dugway Range, though apparently somewhat more complex, does not differ materially from that of the other Basin ranges. The structure is a monocline with westerly dip, the outline of the range being due to faulting with relative uplift on the east. The faulting was apparently later than the outflow of the lavas which form the western foothills. In the Thomas Range ridges of the sedimentary rocks were apparently brought up in the lava areas by faulting parallel to that forming the main range. Gilbert [1] gives the following description of its general structure:

> The Thomas [Granite-Dugway] Range, like the Onaqui, is a simple uplift, presenting throughout its extent a bold escarpment to the east, while at the west its slope is that of its strata, which dip beneath the desert. At Dugway Pass, where we crossed it, its rocks are calcareous but were not found to contain fossils. There is reason, however, to surmise, from stratigraphical data, that they belong to the Silurian series. A short distance north of the pass is an outflow of gray trachyte, and south of it the range is entirely buried beneath a similar lava. Between this and the House Range, but nearer the former, are two low ridges parallel to the first, of like condition and dip, and similarly accompanied by volcanic eruptions.

The old beach lines of Lake Bonneville are especially well marked around the north end of the Dugway Range. Two terraces are conspicuous, the lower and stronger of which has a width varying from a few score to several hundred feet in places especially favorable to wave cutting. Erosion since the recession of the waters of the lake has been so slight that this terrace has not been dissected except along its front, and for long distances it shows only minor irregularities.

GEOLOGY.

The range is composed of sedimentary rocks from Cambrian to Carboniferous in age and of igneous rocks. Granite Mountain is the only large body of intrusive rock. The main area of extrusive rocks is on the western side of the mountain and extends from the Dugway road as far south as Joy.

[1] U. S. Geog. and Geol. Surveys W. 100th Mer. Rept., vol. 3, p. 27, 1875.

SEDIMENTARY ROCKS.

The sedimentary beds were examined by the writer in only two districts, the Detroit and the Dugway.

The lowest stratum exposed in the Detroit district is 2,000 feet of rather uniformly medium-grained quartzite with some beds containing pebbles. On unweathered surfaces the rock is gray but it weathers to reddish brown. Overlying the quartzite is 200 to 300 feet of shale with interstratified sandy beds, which have been considerably metamorphosed and have developed a schistose structure with rather abundant muscovite. Indistinct fossil remains are present. Overlying this is a series of blue limestone and shale at the base that grades up into heavy-bedded blue and gray limestone. Its total exposed thickness is probably fully 4,000 feet.

Fossils were collected (localities 220 and 221) from the shaly limestone series overlying the schistose shales and from several higher horizons, locality 235 being at the highest. These collections were reported on by L. D. Burling as follows:

> Locality 220. The collection contains *Agraulos*, *Ptychoparia*, and *Obolus* sp., an association of species usually found several hundred feet below the horizon of 221.
>
> Locality 221. *Ptychoparia* cf. *P. cordillerae* Rominger, *Protospongia* (spicules), *Agnostus* cf. *A. interstrictus* were obtained from a stratum that is definitely to be correlated with the horizon of the Middle Cambrian Wheeler formation in the House Range, Utah.
>
> Locality 223. The collection appears to contain fossils from two horizons, part of it coming from a shaly limestone which contains *Agnostus* and *Protospongia* (spicules) and is very much the same as locality 221, and part from an oolitic limestone that contains *Ptychoparia* like *P. subcoronata*, *Zacanthoides*, and *Olenoides* sp., and that is definitely to be correlated with the Ute limestone of the Blacksmith Fork section, which is also Middle Cambrian in age.
>
> Locality 227. *Acrotreta ophirensis* was collected from a stratum that is to be correlated with the Middle Cambrian Marjum limestone of the House Range, Utah.
>
> Locality 233. *Ptychoparia* was collected from a horizon that is very close to that of localities 220 and 221.
>
> Locality 235. The collection contains *Crepicephalus texanus* Shumard, *Lingulella desiderata* Walcott, and *Acrotreta idahoensis?* and is from a stratum that is to be correlated with the Upper Cambrian Orr formation of the House Range, Utah.

It is apparent from the stratigraphic and fossil evidence that the rocks in this district range from Lower to Upper Cambrian.

In the Dugway district the rocks, in part at least, lie considerably higher stratigraphically. The general succession in this part of the range is as follows: At the base 4,000 to 5,000 feet of limestone, with interstratified shaly and sandy beds; in places distinctly shaly. This is overlain by at least 2,000 feet of quartzite, with interstratified beds of limestone, which at one place comprise probably more than 200 feet of limestone and shaly beds. Fossils were collected from loose pieces believed to have been derived from the limestone interbedded with the quartzite series at the north end of the range. The fossiliferous fragments were found below the level of the old bench, and it is possible that they may have been transported farther than is apparent.

On these collections Mr. Girty made the following report:

No. 563:
- Fenestella sp.
- Ambocoelia parva?
- Bellerophon sp.
- Proetus sp.

No. 574:
- Campophyllum nevadense?
- Zaphrentis multilamella?
- Productus gallatinensis?
- Productus pileiformis?
- Girtyella? sp.
- Spirifer keokuk var.
- Composita sp.
- Cliothyridina hirsuta?
- Eumetria marcyi.

Lot 574 I may assign to the upper Mississippian, but 563 can not be certainly placed. It is very improbable that it is Pennsylvanian, and its more likely reference is to the upper Mississippian.

Though fossils were not collected from them, it seems probable that the sedimentary rocks exposed in the northern portion of the range are not younger than lower Mississippian and are possibly older than Carboniferous. The rocks between the Dugway and Detroit districts have not been examined by the writer, but it seems probable that most of them are older than Carboniferous.

Sedimentary rocks at the southern end of the Granite Range consist of quartzites and mica schists that have apparently resulted from the alteration of a shale-sandstone series. Though no fossils were found in the sediments, their general character indicates that they are probably not younger than Cambrian.

IGNEOUS ROCKS.

INTRUSIVE ROCKS.

The Granite Range is made up almost entirely of intrusive rock, sedimentary rocks being observed only at its southern end. The intrusive body is complex, being composed of granitic rocks that differ considerably in physical and chemical character, and is most interesting petrologically. The main body of intrusive rock has been cut by many pegmatitic dikes striking with the general trend of the range, which gives it, when viewed from a distance, the aspect of a sedimentary formation.

The northern part of the Granite Range, where examined, is composed of a medium-grained light-colored granite composed essentially of quartz, orthoclase, plagioclase near albite in composition, muscovite, and biotite. The mica is variable in amount, in places being rather abundant and in other places nearly absent. Locally there are segregations of mica, lenses of rock being made up in large part of muscovite. Débris in the valleys extending into the range in the northern part contains abundant boulders of a coarse porphyritic granite carrying orthoclase crystals an inch or less in greatest dimension and a considerable proportion of plagioclase. This granite was not seen in place but must be present in large bodies in the northern part of the range. In the southern part of the range the main body of the rock, so far as observed, is coarsely porphyritic with feldspar crystals an inch or less in length. It contains more biotite and apparently a higher percentage of plagioclase than the granite of the northern part of the range. Although here called granite this rock on more thorough examination may prove to be quartz monzonite.

The entire range is cut by numberless pegmatitic dikes that range in thickness from an inch or less to several feet and in lateral extent from lenses that outcrop for a few feet to those that can be traced for hundreds of feet. Normally they are composed of quartz, orthoclase, some plagioclase, and abundant muscovite, but the proportion of these constituents differs in different dikes and in different parts of the same dikes. Feldspar and muscovite are

abundant in some and of slight importance in others. Numerous veins or "dikes" of coarse white quartz also range in size from mere veinlets to large bodies that can be traced for hundreds of feet. The siliceous dikes make up fully 20 per cent of the rock over large areas. Still other dikes are more basic than the main body of the range. A conspicuous dike of this character in the northern part of the range can be traced for at least several hundred yards and perhaps for 2 to 3 miles. It is a medium-grained green dioritic rock, probably a quartz diorite, though under the microscope the specimens collected proved to be too highly altered to permit determination of the original mineral constituents. The abundant dark silicates have altered to serpentine and chlorite; the feldspars contain much sericitic muscovite; considerable pyrite is present; and quartz forms several per cent of the rock.

The coarse porphyritic granite was probably the earliest rock, though conclusive evidence as to the relative age of this and the finer-grained muscovite granite in the northern part of the district was not obtained. The pegmatitic dikes are later than either, and the veins of coarse white quartz are later than the pegmatites, wherever their relative age was determined. The basic dikes are later than the pegmatite dikes and earlier than the metal-bearing veins of the area. The relation of the basic dikes to the quartz "dikes" was not seen.

In the Dugway district no large bodies of intrusive rock were seen, though there are numerous dikes, several being noted cutting the quartzite in the northwest part of the district. All are highly altered, probably from quartz diorite or quartz monzonite. Farther south at the Buckhorn mine the limestone is cut by a dike probably of similar composition though more highly altered than those to the north.

In the Detroit district the sedimentary rocks are cut by numerous dikes and irregular bodies of intrusive rock, ranging from moderately coarse grained to fine-grained porphyries. All the specimens examined microscopically are of monzonitic composition, being composed of plagioclase and orthoclase with different proportions of the dark minerals, biotite hornblende, augite, and hypersthene, in different dikes. In most specimens examined the biotite is partly and in some specimens very largely altered to augite and iron ore. Accessory minerals are magnetite and apatite, the former being rather abundant. In the fine-grained rock it is difficult to estimate the relative abundance of orthoclase and plagioclase, and a chemical examination might show that some of the dikes would be more accurately classed as diorites.

EXTRUSIVE ROCKS.

Extrusive rocks cover a large area on the western side of the range, between Joy and the Dugway district, but the main body was not examined by the writer. Gilbert has classed them as trachyte, though doubtless a detailed study would show numerous flows of differing compositions.

The extrusive rocks at the north end of the range consist of rhyolitic and latitic flows and tuffs. In the Detroit district they are of essentially the composition of latite, though there are flows of andesite and others that have rather abundant quartz and may prove to be rhyolites, though typical rhyolite was not observed.

In general the flows in this range are similar to those that farther east show a marked similarity over large areas.

AGE AND RELATIONS OF THE IGNEOUS ROCKS.

The age of the igneous rocks can not be closely fixed from local evidence. They are younger than the Carboniferous beds and older than the unconsolidated Quaternary sediments. The relative ages of the intrusive and extrusive rocks have not been ascertained. It is possible that some of the dikes represent the channels through which the extrusive rocks reached the surface. Both in the Detroit district and in the Dugway district the lavas have apparently filled mature valleys, and unless the northern part of the range has had a very different physiographic development from the southern it would seem that the granite body forming the Granite Range must have been uncovered and deeply eroded before the eruption of the lavas.

The similarity of the lavas to those farther east suggests that they are of the same general age, namely Tertiary. The granite is similar to that of the Ibapah stock in the Deep Creek Range and to the granite of the Raft River Range, but whether these are to be correlated with the intrusive Jurassic rocks to the

west or with the intrusive Tertiary rocks to the east is undetermined.

GRANITE RANGE.

There has been very little metal production from the Granite Range. According to unpublished notes by Ellsworth Daggett, who visited the district in 1898, three claims had yielded up to that time about 22 tons of ore, consisting principally of galena containing gold and silver. No other production had been recorded up to 1913. At the time of the writer's visit there was no mining activity in the district, and thorough study of the mines was impossible. There has, however, been some prospecting. The most extensive development has been near the northern end of the range on the property of the Desert Mining Co., on a vein in general paralleling the basic dike already mentioned. (See p. 461.)

The dike, which outcrops prominently, strikes nearly north and dips steeply east. The vein so far as developed is closely associated with the dike. At some points it shows its best development on the footwall, but at other points it is strongest on the hanging wall or even within the dike. The close association of the dike and vein does not seem to indicate a close genetic relation, but rather that the fissure was a line of weakness along which the dike was intruded and later the vein-forming solutions passed.

The vein ranges from a mere stringer to several feet in width, though it is by no means universally present along the dike. It is commonly rather prominently banded. The principal mineral constituents are quartz, fluorite, and hematite and locally a little galena and chalcopyrite. The vein is reported to contain gold and silver. The dike rock within and adjacent to the vein has been altered to a chloritic material, but the granite shows but slight change even at the contact with the vein.

The vein has been prospected at different levels by several hundred feet of drifting, but at the time of visit no large bodies of ore had been found.

Near the contact of the granite and schist at the southern end of the range there are many bodies of coarse white quartz and numerous banded veins composed of quartz and fluorite with some hematite and a little copper carbonate. Veins of this character have been prospected to a slight extent, but no ore bodies have been found. The veins occur both in the granite and in the schist and the vein minerals are similar to those in the northern part of the range.

The granite at the southern end of the range is broken by many joints, most of which contain a film of limonite that indicates that they have been mineralized. There has been no prospecting of this character of material and so far as observed no metals are present other than the iron of the limonite.

DUGWAY DISTRICT.

HISTORY AND PRODUCTION.

By V. C. Heikes.

Dugway district was discovered in 1869 and organized in 1872. It is situated in Tooele County and is reached by wagon road from St. John, the shipping station on the Los Angeles & Salt Lake Railroad, 55 miles to the southwest. A stack furnace [1] was completed in the later part of 1876. The largest production was made from the Buckhorn claim, about a mile from Gilson's old town of Buckhorn and about 650 feet above it. Ellsworth Daggett [2] visited the property in 1898. He reports that a pocket or series of pockets of high-grade ore was found in 1891 in this property and that about 60 tons were shipped, bringing about $68,000 at the smelter. Some of the shipments are said to have contained as high as 1,800 ounces of silver per ton. From another source [3] it is reported that a carload of ore shipped assayed 9.5 per cent lead and 604 ounces of silver and 3.8 ounces of gold per ton, and that in less than four months to the end of June, 1891, the Buckhorn had yielded $22,000. According to Hanauer,[4] there was shipped in 1891 and 1892 from the Buckhorn and other claims in Dugway district 196 tons of ore, containing 232 ounces of gold and 23,800 ounces of silver. Daggett more conservatively estimates the ore shipped at 162 tons and reports that the works visible in 1898 consisted of an open cut about 40 feet square and of several short tunnels and holes running off from it, including a shaft reported

[1] Salt Lake Tribune, Jan. 1, 1877, and Jan. 6, 1878.

[2] Mining notes unpublished.

[3] Mine notes: Eng. and Min. Jour., vol. 51, Apr. 25, 1891, and vol. 52, July 18, 1891.

[4] Hanauer, A., Director of Mint Rept. upon production of precious metals, 1891, p. 224; idem, 1892, p. 172.

to be about 100 feet deep but inaccessible. Most of the ore shipped from the Buckhorn property was reported to Daggett as having come from this open cut and connecting works. About 1,000 tons of ore, mostly lead ore, is estimated to have been shipped from the district previous to 1903, but none is recorded since that time.

In recent years development has been confined largely to that necessary to hold the more promising land in the hope that the building of a railroad through the section will permit profitable sale or exploitation.

ORE DEPOSITS.

The ore deposits are in the quartzite and limestones.

In the northern part of the area the sedimentary rocks have been considerably fissured, and the limestones in these fissured areas have in places been highly silicified, as in the vicinity of the Four Metals mine. At other points the limestone has been blenched and softened, and the rock in many places has been reddened from the oxidation of iron minerals.

The deposits may be roughly classified as replacement fissure veins in the limestone and as fissure veins in the quartzite.

Some prospecting in persistent fissures in the quartzite in the northwestern part of the district has revealed small shoots of galena ore which have a high lead content but are said to contain relatively little silver.

The replacement veins in limestone are also numerous but have been little prospected. The Four Metals mine, the most extensively developed, was idle at the time of visit but is reported to have a depth of nearly 400 feet on the dip. It is said that considerable lead carbonate ore was extracted from the upper levels and shipped. At the time of visit the ore on the dump was mainly mixed lead and zinc sulphides.

Some of the replacement veins in limestone carry copper, but no large deposits of copper ore have been developed. At several places in the district deposits of lead ore have been found at or near the contact of the quartzite and limestone. Their restricted distribution is apparently due to the relative ease with which solutions could circulate along the contact.

The Buckhorn mine is in the southern part of the mineralized area. The deposit is said to have been a small irregular body of very rich ore occurring at the surface, but it was so completely worked out that the writer was unable to get specimens for mineralogic examination. The limestone is cut by a "porphyry" dike too highly altered for its original composition to be determined. The ore deposit, so far as its position could be judged from the workings, was in the limestone adjacent to the porphyry dike. Considerable prospecting has been done both laterally and vertically, but it is reported that no extension of the main ore body or additional ore bodies were discovered.

The opportunities for examining the different deposits were so slight that the writer does not feel justified in expressing a definite opinion on the future of the district. Past experience, however, would seem to indicate that much of the mineralized material is not of sufficiently high grade to make its extraction and shipment profitable under present transportation conditions. There has been mineralization over a large area, and with cheaper transportation facilities some of the deposits could doubtless be worked at a profit. The developments, so far as the writer was able to see them, however, seem to give no strong promise of very large or very rich deposits.

DETROIT DISTRICT.

HISTORY AND PRODUCTION.

By V. C. Heikes.

The Detroit mining district was organized in the fall of 1872 as the Drum district but was abandoned until reorganized under the name of Detroit in 1879. It lies 30 to 35 miles north-northwest of Oasis, in Millard County, extends into Juab County, and includes the camp of Joy. In 1882 the Desert Mining Co. did some mining on the E. P. H. claim, which, at a depth of 100 feet, is said to have produced from an 18-inch vein ore assaying \$36 to \$43 in gold and silver and 14 per cent of bismuth. Ore containing 26.4 per cent of copper was shipped to a plant near Chicago in 1883, and as an experiment some copper ore was shipped to Swansea, Wales, in 1884. During the spring of 1888 a small hot-air blast furnace was erected at the Hot Springs, 11 miles north of

Abraham. After many difficulties it was put in operation by the Alto Mining & Smelting Co., whose headquarters were at the Hot Springs, known then as Wyano post office. All the fluxing ores were supplied from properties in the district within 10 miles of the smelter. Shipments to eastern points aggregated 130,000 pounds of copper bullion, said to have been the largest quantity of copper bars at that time produced in Utah. Subsequently the smelter was destroyed by fire. In 1894 the Ibex property, whose deepest workings were then down to 200 feet, was put in operation by the Utah Gold Mining & Smelting Co., of gold. The Detroit district produced from 1904 to 1917, inclusive, 1,511 tons of ore, containing $11,142 in gold, 5,127 ounces of silver, and 169,250 pounds of copper, valued in all at $45,809. The ore came from the E. P. H., Charm, Ibex, and Copperhead claims. The Ibex group was the largest producer.

ORE DEPOSITS.

All the ore deposits occur in the sedimentary rocks. There has been alteration along fissures in the lava flows, but these are reported to be barren of valuable metals. In June, 1912, all the properties of the district were idle, and

Metals produced in the Detroit district, 1904–1917.

Year.	Ore (short tons).	Gold.		Silver.		Copper.		Total value.
		Fine ounces.	Value.	Fine ounces.	Value.	Pounds.	Value.	
1904	180	155.00	$3,204	768	$440	8,000	$1,000	$4,644
1909	181	33.87	700	757	394	....	....	1,094
1910	89	6.16	127	288	156	26,062	3,310	3,593
1911	66	53.19	1,100	619	328	9,797	1,225	2,653
1912	21	8.99	186	283	174	2,966	489	849
1913	337	101.38	2,096	866	523	29,853	4,627	7,246
1914	39	7.95	164	162	89	7,518	1,000	1,253
1915	184	76.19	1,575	624	317	23,363	4,088	5,980
1916	191	52.24	1,080	343	226	33,543	8,252	9,558
1917	223	44.01	910	417	344	28,148	7,685	8,939
	1,511	538.98	11,142	5,127	2,991	169,250	31,676	45,809

and some ore was shipped to the Hanauer smelter, near Salt Lake.

On January 11, 1895, a smelter for the treatment of ores from the Ibex and Charmed claims was blown in near Leamington. The siliceous character of the ores made the addition of lead ore necessary, and lead concentrates were bought from the Horn Silver mine at premium prices. Some low-grade lead ore was also hauled by wagon from the Utah mine at Fish Springs. During April and May it produced about $35,000 from Ibex ores. The smelter, however, did not prove profitable and went into the hands of a receiver, by whom it was operated until August, 1895, when the Ibex property reverted to the original owners. The total output [1] of the Ibex smelter in 1895, including ores purchased, was 1,531,910 pounds of unrefined lead (including copper) containing 66,577 ounces of silver and 1,328 ounces

[1] Director of Mint Rept. upon production of precious metals, 1895, p. 178, 1896.

the writer had no opportunity to go underground. Since that time there has been considerable activity in the district. G. H. Ryan [2] describes the developments of the different mines in some detail.

Much of the limestone adjacent to the numerous monzonitic porphyry dikes has been recrystallized, and at several points contact silicates were noted, though not in abundance. Sulphides are present with the contact silicates. No extensive development on typical contact deposits has been made.

The deposits that have been worked are replacement fissure deposits and are usually not closely associated with the dikes. The replacement fissures are commonly characterized by a silicification of the limestone adjacent to the fissures and the outcrops are prominent "reefs" of jasperoidal material. The deposits usually

[2] Ryan, G. H., The old Detroit mining district: The Salt Lake Min. Rev., vol. 17, pp. 16-19, Mar. 30, 1916.

contain much pyrite, or limonite that has resulted from the oxidation of pyrite, together with chalcopyrite and its oxidation products and small amounts of other sulphides. The sulphides are said to contain considerable gold and silver, several mines averaging from $10 to $15 in precious metals. Much of the material, however, is not of sufficiently high grade for profitable shipment under ordinary conditions, and attempts at treatment in the district have thus far not been very successful.

In addition to the metalliferous deposits of the range there is an occurrence of topaz near Topaz Mountain. The writer did not visit this locality but according to descriptions the topaz occurs as disseminated crystals in altered volcanic rocks over a considerable area. It is not suitable for cutting.

Bixbyite, an oxide of iron and manganese (essentially $FeO.MnO_2$), has been described by Penfield and Foote[1] from the west side of the range south of the Dugway road, where it is said to be associated with topaz and decomposed garnet in an altered rhyolite.

Some mineralizing action in the volcanic rocks is evident, but so far as the writer is aware no ore deposits have been discovered.

FISH SPRINGS DISTRICT.

By B. S. Butler.

GENERAL FEATURES.

The Fish Springs district is in Juab County, at the north end of the Fish Springs Range, which is the northern extension of the House Range, from which it is separated by a low pass. The nearest railroad point prior to 1917 was Oasis, on the Los Angeles & Salt Lake Railroad, about 60 miles in a direct line from Fish Springs and about 70 miles by the freighters' road. Gold Hill is now the nearest railroad point.

The range contains little timber suitable for either fuel or building. Lumber for buildings and the little required for the mines must be hauled from the railroad or from adjacent ranges, and the cost is high. Gasoline is generally used for power.

The water supply of the camp is obtained from the lowest level of the Utah mine, at a depth slightly below 800 feet.

Analysis of water from Utah mine.[2]

[Recalculated from hypothetical combinations in grains per gallon. Analyst, C. C. Crismon; date, September, 1901.]

	Parts per million.
Total solids	2,255
Volatile and organic matter	239
Silica (SiO_2)	18
Oxides of iron and aluminum ($Fe_2O_3+Al_2O_3$)	13
Calcium (Ca)	64
Magnesium (Mg)	67
Sodium and potassium (Na+K)	591
Sulphate radicle (SO_4)	164
Chlorine (Cl)	1,096

On the flat at the north end of the range several hot springs, some of which have a temperature above 100° F.,[3] furnish a considerable flow of rather highly mineralized water. Fish Springs, near the Thomas ranch, at the eastern base of the range, has a considerable flow of water of fair quality. Good drinking water is obtainable from the artesian wells at Callao.

Farm supplies are obtained from the ranches in Snake and Fish Springs valleys and from Deseret.

The cost of freighting ore from the camp to Oasis is about $12 per ton. Eight-horse teams are able to haul about 15,000 pounds when the roads are in good condition. Twelve to fourteen days are commonly required for the round trip. The total cost of freight from the mines to the smelters is about $15 per ton for ore valued at less than $100 per ton.

HISTORY AND PRODUCTION.

By V. C. Heikes.

The Fish Springs district was organized March 20, 1891. C. C. Van Alstine is reported to have discovered the first mineralized float, which led to the discovery of the Utah and Galena mines in 1890, which later became the principal producers of the district. From its discovery to 1914 the Utah mine has made regular shipments, which, for the full productive period, have averaged 48 cents per ton in gold, 128.35 ounces per ton of silver, and 44.04 per cent lead, a gross average value of $121.58 per ton. The mine has produced 12,997 dry tons of ore containing $6,227 in gold, 1,668,205 ounces of silver, 11,447,930 pounds of lead, valued, at each year's commer-

[1] Penfield, S. L., and Foote, H. W., Am. Jour. Sci., 4th ser., vol. 4, p. 105, 1897.

[2] Meinzer, O. E., Ground water in Juab, Millard, and Iron counties, Utah: U. S. Geol. Survey Water-Supply Paper 277, p. 126, 1911.

[3] Idem, p. 125.

cial prices, at $1,580,186. The dividends paid are reported to total $283,726. From 1891 to December, 1897, the dividends of the company amounted to $152,000, indicating a profit on the ore shipped of $45 per ton and a total cost per ton, including freight and sampling charges, of $76 per ton.

The Galena property adjoins the Utah on the west and is second in importance of production. It is reported to have yielded about 3,000 tons of ore, beginning in 1891, and shipping irregularly for the past ten years. The gross value of the ore produced was about $330,000, out of which $80,000 is said to have been returned in dividends.

Metals produced in Fish Springs district, 1891–1917.

Year.	Ore (short tons).	Gold.		Silver.		Copper.		Lead.		Total value.
		Fine ounces.	Value.	Fine ounces.	Value.	Pounds.	Value.	Pounds.	Value.	
1891–1898	7,325	183.12	$3,785	1,239,269	$892,273	....	....	5,886,940	$211,930	$1,107,988
1899	341	8.52	176	39,129	23,477	....	....	331,826	14,932	38,585
1900	505	12.62	261	71,495	44,327	....	....	480,390	21,137	65,725
1901	512	10.24	212	59,387	35,632	....	....	564,809	24,287	60,131
1902	923	18.29	378	88,659	46,989	....	....	998,483	40,938	88,305
1903	815	15.32	317	53,333	28,800	....	....	761,087	31,966	61,083
1904	846	16.74	346	90,932	52,059	....	....	652,806	28,560	80,965
1905	892	17.84	369	104,358	63,032	....	....	661,572	31,094	94,495
1906	1,161	22.72	470	115,995	77,717	....	....	1,022,205	•58,266	136,453
1907	663	14.76	305	92,001	60,721	....	....	607,247	32,184	93,210
1908	914	29.99	620	124,542	66,007	....	....	885,092	37,174	103,801
1909	665	21.38	442	89,726	46,657	....	....	675,039	29,027	76,126
1910	729	17.79	368	90,390	48,810	....	....	717,929	31,589	80,767
1911	727	22.25	460	79,970	42,384	235	$30	637,054	28,667	71,541
1912	585	21.03	435	68,073	41,865	2,360	390	501,252	22,556	65,246
1913	246	6.71	139	25,705	15,527	1,442	224	184,879	8,135	24,025
1914	331	8.21	170	32,339	17,884	278	37	292,754	11,418	29,509
1915	31	1.05	22	3,923	1,989	....	....	28,412	1,335	3,346
1916	123	1.02	21	20,169	13,271	....	....	115,528	7,971	21,263
1917	125	....	....	10,208	8,411	....	....	63,824	5,489	13,900
	18,459	449.60	9,296	2,499,603	1,627,832	4,315	681	16,669,128	678,655	2,316,464

The Emma claim was the next largest producer, Other producers are the Vulcan, Utah No. 2, Cactus, Spanish, Ada, Wild Cat, Early Harvest, and Last Chance claims.

PHYSIOGRAPHY.

The elevation of the range in the north is about 7,000 feet and farther south is about 8,500. The elevation of the lower parts of the desert valleys is about 4,350 feet, giving a relief of over 4,000 feet. The range, especially on the east, rises abruptly from the desert plain in slopes that are mostly rugged and cut by narrow canyons. Striking features of this in common with other ranges of the region are the wave-cut terraces about its northern end that mark the higher stages of the predecessor of the Great Salt Lake. A road for light traffic crosses the range in the latitude of Fish Spring.

Physiographically, the range is similar to other Basin Ranges. Its block-fault character was recognized by Gilbert,[1] who says:

> The House Range was long ago recognized as a faulted monocline in which the direction of displacement is reversed midway. The northern third of the range [the Fish Springs Range] exhibits a westerly dip, and is faulted along the eastern base; the southern part has an easterly dip and is faulted on the western base.[2] This determination was subsequently confirmed by the discovery of a well-defined fault scarp in the vicinity of Fish Spring, and an obscure and probably very ancient scarp at the western base of the southern division.

That the range is in an immature stage of physiographic development is shown by its rugged character and its narrow canyons.

If the line of thermal springs represents the position of a strong fault along the front of the range [3] the retreat of the front of the range since it was uplifted has not been great.

[1] Gilbert, G. K., Lake Bonneville: U. S. Geol. Survey Mon. 1, p. 283, 1890.

[2] Gilbert, G. K., Report on the geology of portions of Nevada, Utah, California, and Arizona: U. S. Geog. and Geol. Surveys W. 100th Mer. Rept., vol. 3, pp. 27–28, 1875.

[3] Meinzer, O. E., op. cit., p. 126.

The position of Fish Springs Pass has apparently been determined by an east-west fault zone. At the north end of the range the old wave-cut terraces may be followed for long distances. They mark the water level at different stages of Lake Bonneville, the predecessor of the present Great Salt Lake.

GEOLOGY.

SEDIMENTARY ROCKS.

Sedimentary rocks make up a large part of the House Range. Those in the northern part (the only part examined by the writer) are predominantly limestone, interspersed with shaly and siliceous beds and at one horizon by several hundred feet of rather massive quartzite. South of Fish Springs Pass the quartzite outcrops near the divide, and north of the pass near the eastern base of the range.

Fossils were collected from the following localities: 141, float on the east side of Fish Springs Range, the material apparently coming from a horizon considerably below the quartzite; 142, divide just south of the trail from Fish Springs to the Thomas ranch just beneath the quartzite; 143, limestone overlying quartzite east of the Carnation mine. On these collections Edwin Kirk made the following report:

Locality 141. Fish Springs Range:
- Dinorthis fontinalis White.
- Dalmanella pogonipensis Hall and Whitfield.
- Orthis cf. O. tricenaria Conrad.
- Cystid plate genus?

Locality 142. Fish Springs Range:
- Orthis near O. hamburgensis Walcott.
- Dalmanella cf. D. electra Billings.
- Syntrophia calcifera Billings.
- Eccyliopterus michleranus? Hall.
- Bathyurus sp.
- Pliomera sp.
- Sponge n. gen. near Climacospongia.

Locality 143:
- Dalmanella near D. pogonipensis Hall and Whitfield.
- Raphistoma? sp.
- Maclurea annulata? Walcott.
- Asaphus sp.

These three lots contain fossils identical with those obtained by Mr. Walcott in the upper part of the Pogonip limestone of the Eureka district, Nevada. In correlation with formations in the East these beds might broadly be classed as Beekmantown.

From the fossil evidence it seems probable that all the sedimentary rocks in the northern part of the range are of Ordovician or Silurian age, though it is possible that the lowest beds, from which fossils were not collected, are of Cambrian age. Farther south, in the House Range, a considerable thickness of Cambrian sediments is exposed.

IGNEOUS ROCKS.

A large area of flow rocks west of the Fish Springs Range, mapped as basalts in early days, were not examined in the course of the present work, but will not improbably eventually be found to be of a type much more siliceous than basalt.

In the vicinity of the mining district the igneous rocks are confined to a few dikes in the sedimentary rocks. The largest of these up to 50 feet in thickness is near the Utah mine. It strikes generally east. This dike outcrops prominently near the western front of the range A smaller dike near the Emma mine on the south is of the same general character.

Much of the surface rock is stained reddish brown from iron. The freshest specimens collected consist of a light-gray groundmass containing rather abundant phenocrysts of quartz, orthoclase, and biotite. Under the microscope the rock is seen to consist essentially of phenocrysts of orthoclase, quartz, and biotite in a groundmass composed largely of quartz and orthoclase. In some specimens the groundmass is very finely crystalline and the minerals can not be positively determined. Apatite is a rather abundant accessory mineral, and most of the specimens contain secondary minerals, notably calcite, which is locally rather abundant. All the specimens examined are of essentially the same composition, and the rock may be classed as a granite porphyry.

STRUCTURE.

The general structure of the range is relatively simple, but the detailed structure is locally rather complex and will require careful mapping before it can be properly interpreted. The range has been outlined by north-south faults and has been relatively uplifted on the east. The beds have a westerly dip that is locally 35° but that averages considerably less. Lesser north-south faults range in extent from "slips" whose displacement can scarcely be detected to those whose displacement is measured in scores of feet; there is also east-west faulting that is especially marked near Fish Springs Pass, north of which the rocks have

been relatively lowered or thrown to the east several thousand feet. Numerous east-west fissures and faults of small throw have been occupied by dikes or have furnished the channels for the circulation of ore solutions. So far as observed, the east-west faults are the older and are cut off by the north-south faults, which (at least the "slips" seen in the mines) are apparently later than the granite porphyry dikes and the deposition of the ores.

ORE DEPOSITS.

All the ore deposits of the district are replacements of limestone, and all thus far developed are associated with the east-west fissuring. All of them are lead-silver ores, in which the silver content is uniformly high and the gold content low.

UTAH-GALENA FISSURE.

The most productive area thus far developed is associated with the Utah-Galena fissure zone, which trends east, south of and parallel to the largest granite porphyry dike of the district. The fissure dips more steeply than the dike; on the surface the two are about 50 feet apart and on the lowest or 800-foot level of the Utah mine they are nearly 100 feet apart. The ore bodies occur very irregularly. Many of them seem to follow the intersection of the fissures with certain of the limestone beds, but irregularity is too great to warrant any general statement. In prospecting it has been the custom to follow the fissures, even though they become very "tight" and show little indication of mineralization and even though they are interrupted by north-south faults or "slips." Many of these faint leads have been followed to valuable deposits.

Practically all the ore thus far extracted has come from a fissured area south of and underlying the granite porphyry dike. Small bodies of ore have been found at the contact, and the limestone in places has been replaced by sericitic muscovite, but more commonly the shoots lie at some distance though usually not more than 100 feet from the contact.

Some prospecting has been done on the north or hanging-wall side of the porphyry dike on the 800-foot level, and a little ore has been found. In several similar occurrences in the State the larger ore bodies lie on the footwall sides of dikes.

The limestone usually shows little alteration, even within a few feet of an important ore body, and much credit is due to the management of the Utah mine for the skill it has shown in the search for ore.

The primary mineralization in the Utah mine consists of galena and pyrite and a little sphalerite replacing the limestone. Secondary copper minerals in small amount have probably resulted from the alteration of chalcopyrite. Some oxidation of the ore continues to the deepest levels of the mine, and some shoots of ore have been largely altered to secondary minerals, though some bodies of galena ore show only slight alteration. The final products of alteration are commonly cerusite and limonite. Before the oxidation is complete sulphates are locally present in considerable abundance.

The galena alters along the cleavage plane, first to anglesite and then to cerusite. In the shoots where pyrite is present in considerable abundance the basic ferric-lead sulphate plumbojarosite is commonly formed. Shoots of ore in which this mineral is abundant were seen in the mine, and the writer was told that in some places it forms a casing around the high-grade ores. In the more highly oxidized shoots the plumbojarosite has been altered to limonite and cerusite. The writer did not get material in which silver minerals could be definitely determined. Some specimens of galena rich in silver do not contain a recognizable silver mineral. In the oxidized ore horn silver is said to occur.

Migration of the valuable metals appears to have been very slight. The galena was first altered to the sulphate, anglesite, or to plumbojarosite, both of which are relatively insoluble, and later to the carbonate, which is only slightly soluble, so that the lead moved very little. The same seems to have been true in large part for the iron. The pyrite was first altered to sulphate, which in part combined with lead compounds to form plumbojarosite and in part oxidized to limonite, and as already noted the plumbojarosite eventually altered to two relatively insoluble lead and iron minerals, cerusite and limonite. Copper shows more tendency to migrate; the replacement of galena by covel-

lite was noted, and though the ore as a whole contains little copper, the presence of considerable amounts of the secondary copper minerals in small areas suggests considerable migration and concentration of that metal. Silver, like lead, seems to have moved but little during oxidation, probably owing to the presence of abundant chlorine in the ground water (see analyses, p. 465), which caused the formation of the slightly soluble silver chloride as soon as the original silver mineral was altered.

Both the sulphide and oxidized ores are of high grade, and it is doubtful if they have been materially changed in metal content by oxidation, so that it may be expected that ores found at deeper levels will show no marked decrease in tenor.

Only high-grade ore and some associated second-grade ore have been extracted. Most of the second-grade ore can not be profitably shipped under present conditions and is left in the mine, from which it can be extracted cheaply.

The occurrence of the ore in the Galena mine, which is on the same fissure system, is similar to that in the Utah mine. The mine has been developed to a depth of 700 feet and considerable ore extracted. It has not been operated for several years and was not examined by the writer.

In 1918 a mill was built for the treatment of the low-grade ores of the district.

OTHER FISSURES.

The Emma mine has been developed on a fissure a few hundred feet south of the Utah-Galena fissure. The occurrence of the ores is very similar to that in the Utah mine, though the ore shoots are smaller and the ore zone not so extensive. As in the Utah mine, a small dike of the granite porphyry is closely associated with the ores.

The Meteor and other prospects have been operated on this fissure zone but were not active at the time of visit.

Still farther south the Carnation mine has been developed on another essentially parallel fissure. It was opened in the spring of 1912 by an inclined shaft 230 feet deep, which follows the dip of a north-south fault or "slip" that cuts the east-west ore fissure. All development at the time of visit had been east of the fault. The ore, as in other sections of the camp, occurs in irregular shoots, between which the fissure shows little mineralization. The ore mined has been of high grade.

DEEP CREEK RANGE.

By B. S. Butler.

GEOGRAPHY.

The Deep Creek range extends for nearly 50 miles along the western border of Utah in Tooele and Juab counties. The fortieth parallel of latitude crosses the range near its central part. To the west is the Deep Creek valley, a fertile agricultural section watered by streams from the high mountains of the southern part of the range. On the east the range is bordered to the north by the southward extension of the Great Salt Lake Desert and to the south by Snake Valley. Streams from the mountains supply several ranches in Snake Valley.

Prospecting and mining have been most extensive in the northern part of the range in the vicinity of Clifton and Gold Hill but have also been carried on at the Queen of Sheba mine on the west side of the range and on Trout Creek and Granite Creek on the east side of the range.

The nearest railroad point prior to 1917 was Wendover, on the Western Pacific Railroad, 40 to 50 miles from the more active part of the mineral region. In 1917 a railroad was completed from Wendover to Gold Hill. The old overland stage route from Salt Lake to the west passes through a low gap in the northern part of the range and furnished a route to St. Johns, on the Los Angeles & Salt Lake Railroad, which was the most convenient shipping point for the district.

The lack of cheap transportation has been a serious handicap in the development of the district. Only part of the ores are susceptible to milling, and the region has been too remote for cheap smelting, even if a suitable mixture of ores could be had. The advent of the railroad should greatly stimulate development and production.

In the southern and higher part of the range, including the Spring Creek, Willow Springs, Trout Creek, and Granite Creek areas excellent water is abundant, the melting snow from the higher parts of the range sup-

plying the streams until well into the summer. In the northern part of the range, where the elevations are relatively low, the water is scarce and of poor quality. Kane Spring, at Gold Hill, furnishes a small supply that was used for the mill and for stock, and in periods of greatest flow for drinking and cooking. It is far from satisfactory for drinking, however, at least until one becomes accustomed to it. Ocher Springs, which are said to flow approximately 2 gallons per minute, supply the Gold Hill mine. There are other springs from which a small flow of water could undoubtedly be developed. Springs at Clifton furnish water that is used for all purposes but is not of very good quality. Other springs in the eastern part of the district furnish small flows of water. Redding Spring, on the desert east of the range, is said to have an abundant supply of water of good quality. Artesian water of good quality for drinking can be obtained from Ibapah in the Deep Creek valley or from Callao east of the range.

Timber suitable for building, mining, and fuel is present in considerable quantity in the southern part of the range. North of the Overland Canyon, except in the higher parts of Dutch Mountain, cedar and a few other low scrubby trees are the only timber, and over much of the district even these are almost absent. Near the summit of Dutch Mountain there is some timber of fair quality.

The roads are in general good, considering the attention given them, the relatively gentle grades and gravelly soil in the northern part of the range being favorable to the preservation of roads.

The mineralized districts are near the fertile Deep Creek valley, from which they obtain farm products at reasonable prices.

PHYSIOGRAPHY.

The Deep Creek Range in common with other of the Basin Ranges rises abruptly from the desert plateau. The lower parts of the desert have an elevation of about 4,500 feet and the mountains a maximum elevation of 12,100 feet. The southern and central parts of the range are composed largely of quartzite and granite and are steep and rugged, the streams being in deep canyons. The northern part of the range has much less relief and the weaker rocks have resulted in broader valleys and more gentle slopes. Overland Canyon is a low pass across the range which has been a main route of travel through the region since early days.

In the northern part of the range there are no perennial streams and few springs. In the southern part, on the other hand, the larger canyons contain streams that persist throughout the year and furnish water for the irrigation of numerous ranches. The largest stream of the region is Deep Creek, which in the wet season flows to the desert north of the range.

The physiographic features of the Deep Creek Range and vicinity do not differ materially from those of many parts of the Great Basin. To the north is the level barren expanse of the Great Salt Lake Desert with a southward extension into Snake Valley that represents the bottom of an old lake from which the waters have receded. Around the northern end of the mountains the old shore lines are prominent. Flanking the range on either side are the great alluvial deposits characteristic of desert mountains.

The range itself is probably a relatively uplifted block outlined on both the east and the west by north-south faults. Gilbert[1] says:

> The Deep Creek Range, which forms part of the western boundary of the Bonneville Basin, is faulted on both sides. In the vicinity of the old overland road crossing the ridge from Willow Spring to Deep Creek settlement, to which vicinity observation was restricted, the range is flanked on the east by a broad and high alluvial slope. No fault scarp was seen, but near the lower margin of the slope a partial section of the lake sediments shows that they were disturbed during the period of their deposition. The Yellow Clay at one place suffered uplift and erosion before the deposition of the White Marl, so that there is unconformity of dips, and at another point the Yellow Clay and White Marl together are so greatly disturbed that their inclination is toward the mountain. The superficial topography that must have been created by these disturbances was obliterated by wave work, and at the locality of the section the upper edge of the inclined block was planed away in the formation of a terrace of the Provo shore.
>
> On the west side of the range an ancient and nearly obliterated scarp crosses the alluvial slope near its upper edge. On the opposite side of the Deep Creek valley a better preserved fault scarp follows the eastern base of the Gosiute Range. It lies far above the Bonneville shore line and was not critically examined.

[1] Gilbert, G. K., Lake Bonneville: U. S. Geol. Survey Mon. 1, p. 353, 1890.

An east-west structural break across the range in the region of the Overland Pass has thrown the rocks north of the pass relatively down. Erosion has carved narrow canyons in the resistant quartzites and granites, and has produced a very rugged topography. In the softer rocks to the north the canyons have been broadened into a comparatively mild relief.

GEOLOGY.

SEDIMENTARY ROCKS.

The lowest formation exposed (the one that forms the main part of the range toward the south) consists chiefly of quartzite with intercalated schist layers. The schist is composed largely of quartz and mica, muscovite and biotite mica being present in about equal amounts. The quartzite also contains some mica. Near the base of the formation as exposed at Trout Creek in the east side of the range there are some metamorphosed calcareous beds. The thickness of the quartzite was not measured but is certainly several thousand feet, as it makes up almost the entire range at the latitude of Trout Creek, the overlying limestone being present only in the foothills on the west side. No fossils were found, but the general character of the rock has led to its being provisionally referred to the Cambrian, though the base may be pre-Cambrian.

Overlying the quartzite-schist formation are heavy-bedded limestones. In the southern part of the range they are present only on the western side in the foothills. North of the Ibapah mass of granite they form the western part of the range, and in the vicinity of Overland Pass they form a large part of it. North of the pass the Cambrian quartzite is entirely lacking, younger formations making up the entire range. Fossils were not collected from this limestone south of Overland Pass by the writer, but Mr. James Lauton furnished him with a collection said to have come from a horizon 1,000 to 2,000 feet above the quartzite collected just south of Johnsons Canyon.

This collection was examined by Edwin Kirk, who reports the following species: *Orthis* n. sp. near *O. tricenaria* Conrad, *Clitambonites? ionensis* Walcott, *Aparchites ?* sp. Mr. Kirk states that the fossils represent the horizon of the upper part of the Pogonip limestone, which may be correlated with the lower part of the Simpson formation of Oklahoma, which is held to be basal Ordovician by Ulrich.

North of the Overland Pass the structure of the range is complex, and a clear understanding of the sedimentary series can be obtained only by a detailed mapping of the geology of the area.

The south end of Clifton Mountain is composed on the western side principally of limestone, and on the eastern side is made up of a great shale series, much of which is very siliceous, and of some beds of quartzite and shaly limestone. Fossils collected from the limestone talus in the canyon above the spring at Clifton were determined by G. H. Girty as *Zaphrentis* sp., *Menophyllum* sp., *Schuchertella chemungensis* (?), and *Euomphalus utahensis*. Mr. Girty says: "I think that the Madison (lower Mississippian) is present in it, but there are also suggestions of upper Mississippian."

In a collection from the shale series on the east side of the range Mr. Girty determined *Fusulina* sp., *Batostomella* sp., *Rhombopora lepidodendroides*, and *Bellerophon* sp. Mr. Girty states that this collection is of Pennsylvanian age.

No fossils were collected from the limestones between Clifton and Gold Hill. A few hundred yards southwest of Gold Hill a collection (No. 578) was made, from which Mr. Girty determined *Productus pileiformis*, *Martinia* sp., *Spiriferina transversa?*, *Nucula?* sp., *Myalina* aff. *M. sanctiludovici*, *Aviculipecten* sp., and *Edmondia* sp. Mr. Girty states that these are probably upper Mississippian.

The structure in the region between Gold Hill and Clifton is too complex to make it possible without detailed study to give even an approximate correlation of the different areas of limestone that have been included in the monzonitic intrusive. It is probably safe to say that they are all of Carboniferous age.

In the vicinity of Gold Hill south and southeast of the post office and north and northwest of the Gold Hill mine, considerable areas of shaly and siliceous sediments show much alteration and induration.

Dutch Mountain, which forms the northern end of the Deep Creek Range, is composed of limestone and quartzite, which strike northeast and dip northwest at a low angle. At the base of the range to the east, on the road to the Spotted Fawn mine, are several hundred feet

of limestone with interbedded strata of shale and shaly limestone. Overlying the limestone is about 1,000 feet of white and reddish quartzite. Above the quartzite is 100 to 200 feet of micaceous shale that has been considerably metamorphosed with the development of rather abundant mica, giving it a distinctly schistose appearance. Overlying the shale and extending to the summit of the mountain is a series of limestone and interbedded shaly limestone whose exposed thickness is about 2,000 feet.

Fossils were collected in débris just above the shale beds, and it is believed that they were derived from the limestone not more than a few hundred feet higher. From this collection Mr. Girty determined *Zaphrentis* sp., *Batostomella* sp., *Fenestella* sp., *Chonetes* sp., *Productus punctatus*, and *Straparollus* sp.

Fossils were also collected near the summit of the range above the Spotted Fawn mine, among which *Fenestella* sp., *Cystodictya* sp., and *Productus cora?* were determined.

Mr. Girty considers that both collections are probably upper Mississippian.

The ages of the quartzite and of the limestone underlying the quartzite have not been determined by fossil evidence. At no other locality within the State has the writer noted sediments as highly metamorphosed as the micaceous shales in rocks known to be younger than Cambrian.

IGNEOUS ROCKS.

The area contains large bodies of igneous rocks, by far the more important being intrusive rocks, though there are lesser bodies of extrusive rock.

EXTRUSIVE ROCKS.

Lava flows so far as observed are confined to the northern end of the range. They are present northwest of Dutch Mountain, where Deep Creek has cut a canyon in them, and east and southwest of Clifton Mountain on the flanks of the main range. Several small areas of lava near the bottom of the valley north of Clifton lie entirely within the range, surrounded by limestone and quartz monzonite, and appear to have flowed over the area after the valley had been eroded to essentially its present form.

The flow rocks vary considerably in appearance, but those observed were of medium composition—latites and quartz latites, with some that might be classed as andesites. Their relation to the sedimentary rocks and to the intrusive rock was seen only in the valley north of Clifton, where they appear to occupy valleys eroded in both the sedimentary and the intrusive rocks and are consequently distinctly later. They may be provisionally regarded as of Tertiary age in common with most of the effusive rocks of adjacent portions of Utah and Nevada.

INTRUSIVE ROCKS.

The intrusive rocks consist of stocks of granitic rocks and of dikes cutting both the sedimentary rocks and the larger intrusive bodies.

STOCKS.

Ipabah stock.—The largest body of intrusive rock exposed in the area centers in Mount Ibapah, in the central part of the range. It extends along the range for about 6 miles with a width of approximately 8 miles, and is thus one of the largest intrusive bodies in the State.

The rock as seen on both sides of the range appears to be uniform. It has a very coarse-grained granitic texture containing feldspar crystals as much as an inch in greatest dimension. Under the microscope and in the hand specimen the rock is seen to be composed of orthoclase, quartz, and biotite, but with considerable plagioclase near oligoclase in composition. The chief variation is in the amount of quartz. Some of the plagioclase crystals are inclosed in the larger orthoclase crystals. Not infrequently the plagioclase crystals are surrounded by a fringe composed of a fine micropegmatitic intergrowth of feldspars. Albite is rather abundant intergrown with orthoclase. Muscovite occurs as an alteration product of biotite and to a slight extent as an alteration of feldspar. Accessory minerals are rare. There is a little magnetite and occasional crystals of zircon and apatite. The rock is classed as granodiorite, though it closely approaches a soda-rich granite. The composition of the rock is shown in an analysis by R. C. Wells, from a specimen from Granite Canyon. (See p. 96.)

Gold Hill and Clifton stock.—In the Gold Hill and Clifton district, in the northern part of the range, the sedimentary rocks have been intruded by a body of quartz monzonite which

has been exposed by erosion and occupies numerous areas amid the sedimentary rocks. Many of the smaller limestone bodies appear to be underlain at no great depth by monzonite, and in fact appear to be sedimentary blocks resting upon monzonite. The general arrangement of the sedimentary and the intrusive rocks suggests that the present surface is near the more or less irregular top of an extensive intrusive body that occupies a large area in the district. The larger bodies of quartz monzonite (that forming the northern part of Clifton Mountain, for example) probably once extended to considerably greater heights. Were the present surface reduced a thousand feet the area now occupied by sedimentary rocks would probably be much smaller and that occupied by the intrusive rocks correspondingly larger. In fact, some rather large areas of sedimentary rocks would probably give place entirely to intrusive rock at even less depth.

The main intrusive rock throughout the Gold Hill and Clifton district is generally uniform in appearance and not markedly varied in composition. On fresh breaks it is a rather dark greenish rock of medium texture, in which orthoclase, plagioclase, biotite, and hornblende are readily recognized. Quartz is present, but in most hand specimens is not conspicuous. Under the microscope the rock is seen to have a typical granitic texture and to be composed of orthoclase, plagioclase, quartz, biotite, and hornblende, with magnetite, apatite, sphene, and zircon as accessory minerals. The orthoclase appears to be nearly as abundant as the plagioclase, which has a composition close to andesine. Mineralogically the rock is a typical quartz monzonite. An analysis by R. C. Wells shows the chemical composition of a representative specimen collected near Gold Hill. (See p. 96.)

Locally the rock differs considerably from the general type. Adjacent to the ore bodies at Gold Hill, for example, it is distinctly porphyritic, being composed of phenocrysts of feldspar, mostly plagioclase, biotite, and hornblende in an aplitic groundmass composed largely of quartz and orthoclase with magnetite and apatite as accessory minerals, the apatite commonly showing a very striking pleochroism from dark brown to deep purple. In mineral composition it differs chiefly in having more quartz and a little more orthoclase.

DIKES.

Occurrence and character.—Dikes and small bodies of the quartz monzonite in the sedimentary rocks commonly have a porphyritic texture but usually do not differ materially in composition from the main body of the rock.

Dike rocks later than the main intrusive bodies cut both sedimentary and intrusive rocks in the vicinity of the intrusive centers. These dike rocks vary greatly in character but may be separated into those more basic and those more siliceous than the main intrusive bodies.

Basic dikes.—All the basic dikes noted in the vicinity of Clifton and on the east side of Clifton Mountain that cut quartz monzonite, are dark gray in color, and are rather sparingly sprinkled with phenocrysts of quartz and feldspar.

A specimen taken from a dike about half a mile west of Clifton is seen under the microscope to be composed of quartz, plagioclase, and augite phenocrysts in a groundmass of plagioclase laths and augite. The feldspar, both of the phenocrysts and groundmass, is near andesine in composition. The feldspar and augite of the groundmass have the typical intersertal structure characteristic of diabase dikes. A somewhat similar specimen from the east side of Clifton Mountain contains some orthoclase, both as phenocrysts and in the groundmass. Dikes at other points are apparently somewhat more basic than those described but are too highly altered for their original composition to be determined.

In and adjacent to the granite mass in the southern part of the range basic dikes were observed only in the schist south of Granite Canyon, where several diorite dikes are present. Specimens that were examined microscopically are composed essentially of plagioclase and hornblende with a little quartz and iron ore. Only small areas of the main granite mass were examined and it is entirely probable that basic dikes are present in it as well as in the quartz monzonite in the northern part of the range.

Siliceous dikes.—Siliceous dikes, both aplitic and pegmatitic, are rather numerous in the intrusive rocks.

Numerous coarse pegmatitic dikes, composed essentially of quartz, orthoclase, and muscovite, with a little local tourmaline, and numer-

ous "dikes" or veins of coarse pegmatitic quartz, are associated with the large Ibapah stock of granite, especially in the vicinity of the Queen of Sheba mine. The true pegmatite appears to grade into the pegmatitic quartz. Similar dikes are reported well within the main granite mass. Mr. James Lauton gave the writer specimens of beryl said to have come from a quartz "dike" or vein in the main granite mass. In the quartz monzonite in the Gold Hill and Clifton area typical pegmatites are less abundant, though some are present in the area north of Clifton.

A pinkish rock outcropping in the rather flat bottomed valley 1 to 1½ miles northwest of Clifton appears in the hand specimen to consist largely of feldspar and under the microscope to be composed of rather abundant phenocrysts of plagioclase near oligoclase and of a few of hornblende in an aplitic groundmass of quartz and orthoclase. Accessory sphene is especially abundant. The relations of this more siliceous rock to the main body of quartz monzonite were not clear on account of poor exposure, but it appears to be intrusive into the main body. A very similar rock at the Gold Hill mine was probably intruded into the main body before the quartz monzonite was thoroughly solidified and in consequence more or less blending occurred. In the region northwest of Clifton small dikes of an aplitic rock are composed of quartz, orthoclase, some plagioclase, hornblende, and tourmaline, with abundant accessory titanite and apatite.

In this same region a coarse pegmatitic dike, composed largely of crystals of pink feldspar several inches in greatest dimension with a lesser amount of lenticular quartz, contains scattered sheathlike bodies of fibrous amphibole that have been partly altered to biotite, muscovite, and orthoclase. The larger of these bodies are 6 inches in diameter and a foot or more in length. They readily fall to pieces when taken from the rock. What appear to be remnants of the original mineral are occasionally seen as dark-green fibers of amphibole.

Only a few hundred feet away other pegmatitic dikes contain metallic minerals in considerable amount. (See p. 476.)

RELATION AND AGE.

The different intrusive rocks cut all of the consolidated sedimentary rocks in the range. Their relation to the flow rocks was not positively determined, but they appear to be earlier. (See p. 472.)

No known evidence indicates more than one period of important intrusions in the district, though some later dike rocks may be associated with the lava flows. It has not been shown that the granite of the Ibapah Mountain mass is of the same age as the quartz monzonite of the Gold Hill and Clifton area, but it seems most natural to consider it so in the absence of positive evidence. The Ibapah mass is the deeper-seated rock, being intrusive into Cambrian and Ordovician sediments, whereas the quartz monzonite is intrusive into Carboniferous sediments. Here, as in the Little Cottonwood and Park City districts, the deeper-seated rock is the more siliceous.

Both the aplitic and pegmatitic dikes intrude the main intrusive masses and are, with little doubt, differentiation products of its crystallization. Some aplitic dikes appear to have been intruded so soon after the solidification of the stock that their margins blended with the main intrusive mass and definite walls are lacking. Both aplitic and pegmatitic rocks include gradations from siliceous rocks having essentially the mineral constituents of the main intrusive, but with more orthoclase and quartz and less of the dark silicate and plagioclase, through rocks composed essentially of quartz and orthoclase with minor amounts of other constituents, to rocks in which tourmaline is important, to those containing metallic oxides and sulphides, and to the tourmaline quartz veins that are so abundant in the district.

The relation of the basic dikes to the other rocks is not so clear. Many intrusions of medium composition were followed by intrusions of both more basic and more siliceous rocks that have resulted from the differentiation of the magma. The evidence is conclusive that the more siliceous rocks in this region have resulted from such a differentiation, and the same is probably true of the basic rocks, though the evidence in regard to these is by no means so conclusive.

STRUCTURE.

The detailed structure of the district is altogether too complicated to be determined in a brief reconnaissance. The major structural features, however, are useful in aiding mining

development, though of course study of the details is essential in individual developments.

The general outline of the Deep Creek Range is probably due to faulting along both its east and west sides.[1] The deep Overland Gap across the range is cut by erosion along a structural break, whose position is determined by the doming of the sediments apparently resulting from the intrusion of the quartz monzonite. The intrusion of a large body of material into the sedimentary series greatly disturbed the earlier rocks and caused divergent dips and strikes within very small areas.

That there has been some faulting since the intrusion of the igneous rock and since the deposition of the ores is shown by gouges and slickensides in both intrusive rocks and ore deposits, and this later faulting may be of large importance in mine development. That there has also been some movement along the contacts of the intrusive rock with the sediments is probable, as these would naturally be planes of weakness. It should be kept in mind, however, that the general relations of the igneous to the sedimentary rocks result from the intrusion of the igneous material and not from the complex faulting of sedimentary rocks deposited on an earlier granitic basement.

HISTORY AND PRODUCTION.

By V. C. Heikes.

CLIFTON DISTRICT.

The Clifton district is in Tooele County, 43 miles south-southeast of Wendover, on the Western Pacific Railroad. Gold Hill and Clifton are the principal camps of the district. The first discovery of mineral is said to have been made in 1858, but the hostility of the Indians retarded development until 1869, when the first mining operations were begun and the district was organized (on Oct. 18). Huntley[2] reviews the conditions in November, 1880, as follows:

> A smelter was built in 1871 and was moved in 1876 to a spot 6 miles distant by the St. Louis Consolidated Co. Probably 150 tons of bullion were produced. * * * About 50 claims, of over 500 located, are still worked occasionally. Little has been done since 1877.

[1] Gilbert, G. K., Lake Bonneville: U. S. Geol. Survey Mon. 1, p. 353, 1890.

[2] Precious metals: Tenth Census U. S., vol. 13, p. 456, 1885.

The smelter built in 1871 is reported by an old resident[3] and mine owner of the district to have been a stack furnace operated with three blacksmith bellows. Three tons of lead bullion represented the results of the first operations. In 1872 Gilbertson & Berry's furnace was built at Clifton to treat the ores from the Gilbertson mine at Gold Hill. About 30 tons of lead bullion[4] shipped to Salt Lake averaged \$93 in silver per ton. A few years later this furnace was moved to Gold Hill by J. W. Harker. The crude ore smelted carried about \$4 in gold, 30 ounces of silver per ton, and 25 to 30 per cent of lead.

Activity in mining did not again assume importance until 1892, when a mill was put in operation at Gold Hill. The ores treated were from the Cane Springs, Alvarado, and Gold Hill claims, which were credited with a total gold production of \$207,986 from September, 1892, to November, 1895. Of this total probably half the ore and more than three-fifths of the gold came from the Alvarado mine. No complete record of the amount of ore handled exists, but a partial record shows 9,475 tons of ore milled from August, 1892, to May, 1894, assaying \$14 per ton and yielding \$97,393, or \$10.28 per ton. At the same rate, the total ore worked was about 19,000 tons.[5] The gold produced was very pure, some of it 0.946 fine.

The Midas property is about 3 miles southeast of Clifton. In 1896 and prior to that year 95 tons of ore averaging \$56 in gold and a trace in silver per ton were treated at the Cane Springs mill and shipped to the smelter. In 1902 a 40-ton cyanide mill was constructed and treated 622 tons with a reported saving of \$15 per ton in gold. In 1904 the mill was operated again, but the results were unfavorable, and the property was practically abandoned.

The Clifton district again revived in 1909, when the Alvarado claim produced some gold ore of shipping grade, and the Western Utah Copper Co. developed the Gold Hill and Cane Springs groups and opened considerable lead and low-grade copper ore. However, none of the ore was shipped, as the plan was to smelt it at some future time in the district.

[3] Dunyon, Isaac, Salt Lake City, personal interview.

[4] Fabian, Bentham, Resources of Utah, 1872, p. 16, Salt Lake City, Utah, 1873.

[5] Daggett, Ellsworth, unpublished mining notes.

SPRING CREEK DISTRICT.

The Spring Creek district, in Juab County, about 16 miles south of Ibapah, a settlement in the Deep Creek region, and 105 miles northwest of Oasis on the Los Angeles & Salt Lake Railroad, was organized June 4, 1891. The only producing property in the district was the Queen of Sheba, which has been worked intermittently and whose total gold output probably does not exceed $40,000.

JOHNSON PEAK OR TROUT CREEK DISTRICT.

The Johnson Peak or Trout Creek district is in the western part of Juab County, 20 miles south of Callao, Utah. In 1912 some copper ore containing gold and silver was shipped from it to the smelter near Salt Lake.

GOLD HILL AND CLIFTON DISTRICT.[1]

ORE DEPOSITS.

The ore deposits differ greatly both in occurrence and in the metal constituents for which they are valuable. Prior to 1917 the gold deposits had been the most productive, but since then lead, silver, copper, tungsten, and bismuth have been mined. Probably all the ores were not formed at exactly the same time, but there is no known evidence to show more than one general period of mineralization.

The deposits may be separated into replacement veins in the intrusive rock and replacement deposits in the sedimentary rocks. Some deposits may extend from one type of rock into the other, but in general they are distinct.

REPLACEMENT VEINS IN QUARTZ MONZONITE.

Replacement veins in quartz monzonite range from those that contain much feldspar and are closely allied to pegmatite, if indeed they may not be more properly called pegmatite, to quartz-tourmaline veins, to quartz-carbonate veins in which carbonates are abundant and tourmaline of minor importance, and to quartz and quartz-carbonate-sulphide veins. The chief value of the deposits are in tungsten, copper, lead, or gold.

[1] Since this report went to press a description of the region by J. F. Kemp and Paul Billingsley has been published in Econ. Geology, vol. 13, pp. 247-274, June, 1918.

PEGMATITIC VEINS.

The largest pegmatitic veins noted in 1912 outcrop in a flat-bottomed valley about a mile northwest of Clifton on the Reaper group of claims. The natural exposures are rather poor. The three prospects opened at the time of the writer's visit are probably on separate veins, though it is possible that two of them are on the same vein. The material of one vein on which a shaft has been sunk 30 to 35 feet is orthoclase quartz, a green fibrous amphibole, tourmaline, a little epidote, and a carbonate containing iron, calcium, and probably other constituents. Apatite is rather plentiful. Danburite, which is rather abundant in the quartz-tourmaline veins, was not noted but may be present. Magnetite is rather abundant. Other metallic minerals are powellite and scheelite. Gold is said to occur in the deposits and it was in search of this metal that the shaft was sunk. Stains of copper carbonate are present but are not abundant. The powellite in the vein plainly resulted from the alteration of molybdenite. Considerable molybdenite appears in picked specimens but forms only a small percentage of the whole ore. Tungsten is present in scheelite and perhaps in other minerals, though none was recognized in the specimens collected.

At the time of visit the width of the dike or vein had not been disclosed, but it is at least several feet. Adjacent to the shaft a body composed largely of scheelite 18 to 24 inches in thickness had been exposed for 4 or 5 feet along the strike and 3 or 4 feet below the outcrop. Deeper in the shaft other apparently smaller bodies of scheelite were exposed. The scheelite occurs in large crystals, some of which are 4 inches long. One block of nearly pure scheelite ore on the dump was estimated to weigh fully 200 pounds.

The bodies of high-grade ore appear to occur as lenticular masses in the vein and suggest segregations of the scheelite through the pegmatite material of which the scheelite is an essential part. The scheelite was one of the earliest minerals to form. Much of it is in well-formed crystals and little of it includes the other minerals.

Considerable development work on this vein has been done since the writer examined it, and some scheelite has been shipped.

A few hundred feet from the opening just described a shallow shaft on a similar or possibly on the same vein showed no scheelite. A short distance farther north a shaft about 10 feet deep has been sunk on a pegmatite dike composed essentially of feldspar quartz and fibrous amphibole, which occurs in sheaf-like aggregates 6 inches in maximum diameter and a foot or more in length. The original amphibole has been partly altered to a light-green amphibole, chlorite, and biotite, and some muscovite. No sulphides or oxides of iron were noted.

The quartz monzonite adjacent to these veins has been altered for a short distance to quartz muscovite and chlorite with some oxide of iron. The chlorite may have resulted from the surface alteration of some magnesian mineral formed by the hydrothermal action of the vein-forming solutions, but no remnants of such a mineral remained in the sections examined.

QUARTZ-TOURMALINE VEINS.

Closely allied to the pegmatitic veins are the quartz-tourmaline veins that are abundant in the quartz monzonite between Clifton and Gold Hill. These veins vary considerably in composition, but all contain abundant quartz, tourmaline, some pyrite and chalcopyrite, carbonate, amphibole, and diopside, and considerable apatite and sphene. Vesuvianite, garnet, epidote, and galena occur in some of the veins. Danburite, a borocalcium silicate ($CaB_2(SiO_4)_2$), was noted in numerous specimens and may prove to be locally abundant. Zircon, rutile (some of which results from the alteration of titanite), and orthoclase are present in many specimens. Fluorite was noted, but is not an important constituent.

In several of the veins radiating laths several inches in length appear to be the alteration products of some mineral, possibly tourmaline. Under the microscope they are seen to be composed of orthoclase, microperthite, quartz, muscovite, considerable carbonate, and tourmaline in small amount. The tourmaline occurs as rather large crystals with pleochroism from dark green to nearly black and as very fine radiating needles with a pleochroism from nearly colorless to slate-blue. The blue tourmaline is doubtless later than the brown and may have formed from its alteration. The form and habit of the altered crystals are similar to those of the tourmaline of the veins, and the brown crystals of tourmaline suggest remnants of the original mineral.

The principal primary metallic minerals of the veins are magnetite, hematite, pyrite, chalcopyrite, and in some veins galena. Scheelite in small amount was noted in the veins in several parts of the area and is apparently a common constituent. Its most abundant occurrence in veins is in the Lucy L. group of claims, where the vein is in the quartz monzonite, but close to the limestone contact the deposit has some of the characteristics of the contact deposits. The associated minerals are carbonates, quartz, diopside, a green amphibole, brown and green mica, vesuvianite, a mineral resembling garnet but showing usually strong birefringence and in many specimens twinning, orthoclase, danburite, epidote, and small amounts of allanite, sphene, and apatite.

The metallic minerals in addition to the scheelite are magnetite, hematite, sulphides of iron and copper and their oxidation products, and molybdenite and its oxidation products. Tin has been reported from the veins but was not noted by the writer. The character of the veins is similar, however, to those in which tin occurs, and it would not be surprising to find that metal in small amount.

The typical alteration of the quartz monzonite adjacent to the veins is to a rock composed essentially of quartz, biotite, and muscovite. A green pleochroic mica and chlorite are commonly abundant but are probably alteration products of the brown mica. Tourmaline, carbonates, sphene, and apatite are common constituents of the altered wall rock. A fragment of wall rock from the Lucy L. scheelite vein is composed of diopside and a green pleochroic hornblende, carbonate, epidote, and several crystals of allanite.

The abundance of magnesian minerals both in the veins and in the altered wall rock is characteristic. Another characteristic is the presence of an unusual amount of titanium, usually as titanite. Boron minerals are also abundant. Tourmaline is an important constituent of most of the veins, and danburite is common. So far as the writer is aware this is the only district in the State from which danburite has been reported.

The solutions forming these veins must have been rich in silica, boron, magnesia, potassium, iron, and titanium, and must have carried sulphur, copper, lead, tungsten, and molybdenum. Sodium was largely removed and calcium to some extent, though the carbonate and other calcium minerals present in some of the veins may account for a part of the lime contained in the original quartz monzonite of the wall rock.

Ores of this type are valuable chiefly for their copper and possibly for their tungsten content. As a rule they are too low grade to be shipped at a profit under conditions existing before the advent of the railroad and consequently have had comparatively little development. Some copper ore of fair grade has been found, but as a whole the development to date is not very encouraging. Scheelite was noted in several veins, but not much ore of good grade in commercial quantity has yet been proved; however, the possibility of finding this mineral should be kept in mind. Considerable development has been done on the Pole Star, Clifton Copper Belt, Frankie, Lucy L., Gold Bond, and other groups.

Some veins in the district contain no tourmaline and little, if any, magnesian silicates, but are otherwise similar to those described. The most valuable constituent of these is copper.

QUARTZ-CARBONATE LEAD VEINS.

In the quartz monzonite forming the northern part of Clifton Mountain east and northeast of Clifton many veins, composed essentially of quartz and carbonate, carry small amounts of galena and other sulphides. Their chief value has been in lead and silver.

Most of the veins outcrop prominently and can be traced for hundreds of feet. The general strike is about N. 60° E. and the dip is steeply east; both, however, vary considerably. Most veins show a banded structure, in some indistinct and in some well developed. The relative amounts of quartz and carbonates differ greatly in different veins and in different parts of a single vein. Some veins are composed very largely of carbonates—probably iron-magnesium-calcium carbonates of variable composition.

The wall rock has undergone pronounced sericitization. Chlorite and a green pleochroic mica are present, but magnesian minerals appear to be less abundant than in the wall rock of the tourmaline quartz veins.

Comparatively little prospecting has been done on this type of vein, though small bodies of ore of good grade have been developed north of Clifton.

QUARTZ AND QUARTZ-CARBONATE GOLD VEINS.

Numerous veins that carry gold in amounts that have encouraged prospecting occur from $1\frac{1}{2}$ to 3 miles north and north-northeast of Clifton and have yielded a small production.

Through this section a body of quartz, in many places several hundred feet wide, can be traced on the surface northward for a mile or more. The thickness of the "vein" is probably not so great as the width of the outcrop, for it may dip west at a low angle, though the exposures do not indicate this conclusively. The quartz body is composed largely of fine crystalline quartz, cut by veins of coarser quartz, some of which are of amethystine color. In some areas the rock carries considerable carbonate and, it is said, a little lead and some gold.

The veins that have been prospected for gold are small, not more than a few feet in thickness, but many of them can be traced for considerable distances along the strike. Those examined trend predominantly northwest.

Quartz is the prevailing gangue with a subordinate amount of carbonate. Pyrite and chalcopyrite are usually present in small amount, and galena and sphalerite were noted. Specular hematite is abundant in small flakes in much of the gangue, giving it a dark color. The gold is said to occur free. The alteration of the wall rock does not differ materially from that of the quartz-carbonate lead veins. A specimen of wall rock from the Troy vein showed typical sericitization of the feldspars and alteration of the magnesian minerals to chlorite. The chlorite has possibly formed by the surface weathering of magnesian mica.

Some very rich ore is said to have been produced from a pocket in the Troy vein. This pocket, however, was very limited in extent, and prospecting on the veins has not revealed additional pockets. Other veins are said to contain ore of milling grade, but these have not been extensively opened, nor have milling tests been made.

DEPOSITS IN SEDIMENTARY ROCKS.

Deposits in sedimentary rocks may be divided into contact deposits, or those forming in the immediate vicinity of the intrusive contact, and replacement fissure deposits, or those in which ore minerals have replaced sedimentary rock along fissures some distance from the contact.

CONTACT DEPOSITS.

Contact deposits occur in the sedimentary rocks at or near the quartz monzonite contact and contain, as gangue minerals, silicates and other minerals generally recognized as forming only at relatively high temperatures. In this district they may be divided into two principal classes—namely, those that have their chief metal values in copper and those in which gold is most important.

COPPER DEPOSITS.

At numerous points between Gold Hill and Clifton, along the contact of the limestone and quartz monzonite, the limestone has been replaced by garnet, diopside, amphibole, epidote, tourmaline, axinite (noted in several places), magnetite, specularite, sulphides of iron and copper, and here and there a little galena and sphalerite. Carbonate, which is commonly present in considerable quantity, is probably in part at least a recrystallization of the original limestone, to which iron has been added. The iron oxides are commonly abundant, as is also tourmaline. Apatite and titanite are present in small amount. The sulphides of iron and copper have been largely altered to oxides and carbonates to the depth to which prospecting has extended—which is rarely more than 100 feet below the outcrop.

Many of these deposits are mineralogically very similar to some of the veins in the quartz monzonite and not improbably contain tungsten minerals. Prospecting has developed in them some copper ore of fair grade, though not sufficiently rich for shipment before the advent of the railroad.

The deposits occur at intervals along the contact, and the reason for their distribution is not everywhere clear. Some appear to be associated with fissuring of both the quartz monzonite and limestone. Others have no apparent relation to structure.

Another type of contact deposit is exemplified by large bodies of fine-grained cherty quartz that have replaced the limestone. This quartz commonly contains some limonite, probably resulting from the oxidation of sulphides, and has a jasperoidal character. Large "reefs" of this character may be seen south of the road between Gold Hill and Clifton, about 1½ miles from Clifton. A little prospecting has been done about the margins of these reefs and some stains of copper carbonates were seen, but no ore bodies have been found.

GOLD DEPOSITS.

General features.—Contact deposits valuable chiefly for their gold content are present at several localities and have furnished the chief output of the district. Some of these deposits occur some distance from large bodies of the intrusive rock but contain as gangue minerals the silicates that characterize contact deposits.

This type of deposit, which has been worked in at least four mines, is strikingly uniform in mineral composition and mode of occurrence wherever it has been developed. It is a replacement of certain beds of limestone by "contact" silicates and sulphides. Much of the limestone bed shows continuous alteration for a considerable distance along its strike and dip, but the ore is confined to "shoots" within this mineralized bed.

The most characteristic mineral of the altered limestone is wollastonite, which forms a large percentage of all the ore. A green, slightly pleochroic pyroxene with optical properties near diopside is universally present in small amount and is locally abundant. Garnet and vesuvianite were noted in ore from the Midas mine. The principal sulphides are chalcopyrite and bornite and some molybdenite. Specimens from the Midas dump contained arsenopyrite, but this mineral does not appear to be an important ore constituent. The sulphide minerals differ in amount in the different ore bodies and in different parts of the individual ore bodies. In the Alvarado and Midas mines sulphides were not abundant, but in the Cane Springs mine chalcopyrite and bornite are rather plentiful. The sulphides formed in part contemporaneously with the gangue minerals and in part later in interstitial spaces and in fissures in the silicates.

The alteration of chalcopyrite, the earliest sulphide, begins around the margin of the grains and along fissures and proceeds inward till all the chalcopyrite has changed to bornite. A gray mineral, probably chalcocite, has partly replaced the bornite and in some instances the chalcopyrite. The alteration to chalcocite is, however, usually confined to thin envelopes surrounding the other sulphides.

The gold occurs in large part as free gold and probably to some extent also in the sulphide. The free gold, like some of the sulphides, occurs in part between the silicate crystals, suggesting that it was deposited slightly later. The gold shows a distinct tendency to crystal form.

The richest gold ore seen by the writer is somewhat oxidized, and shows a distinct tendency to concentrate along small fissures, not uncommonly in association with copper sulphides. Some specimens, however, contain no sulphides, and the native gold appears to have been deposited as an original constituent. A large part of the gold, indeed, has probably been obtained from ore that contained very little sulphide. The bullion from the Alvarado and Midas mines particularly is exceptionally fine.

Alvarado mine.—The Alvarado mine, about a mile east of the Gold Hill post office and about one-fourth of a mile west of the Gold Hill mine, is in limestone at the contact with quartz monzonite. The contact is irregular, dikes of the quartz monzonite extending into the limestone, and fragments of the limestone being partly inclosed in the quartz monzonite. The ore, which is typical of the contact gold deposits, replaces the limestone irregularly and extends along the contact for several hundred feet. In places it is stoped to a width of 40 feet, and at other places it nearly pinches out. The mine has been opened to a depth of about 200 feet. The grade of the ore varies greatly from place to place, and there is usually no sharp distinction between ore and waste, the material mined as ore being dependent on the possibility of profitable treatment. The ore treated at the mill is reported to have yielded gold to the value of about $15 per ton, with $4 to $5 lost in tailings.

Cane Springs mine.—The Cane Springs mine is about one-fourth of a mile west of the Gold Hill post office. The sedimentary series consists of rather massive beds of limestone interstratified with coarse siliceous shale, approaching quartzite. The principal ore body has formed as a replacement of a coarsely crystalline limestone. The principal minerals, wollastonite and garnet, and the minor minerals are all typical of the contact gold deposits, although no quartz monzonite or intrusive rock of any kind was observed near the mine.

The ore is similar to that of the Alvarado mine except that it has a considerably higher sulphide content. The ore body has been faulted in several places, but the movement was slight and no serious trouble was experienced in following the ore shoot. The shoot, where best developed, is about 150 feet along the strike and from a few feet to 20 feet in width. So far as developed, the shoot decreased both in length and in thickness with increasing depth.

The mine has been developed by an incline shaft to a depth of about 160 feet.

Midas mine.—The Midas mine is near the south end of Clifton Mountain about 3 miles south of the Clifton camp. The sedimentary rocks in the vicinity are limestones with intercalated siliceous beds. These have been invaded by the quartz monzonite which outcrops near the mine and has been encountered in the mine workings.

At the time of the writer's visit the mine was closed. The main ore body seems to be a replacement of a 4-foot bed of limestone lying between siliceous strata. This bed is not in immediate contact with the intrusive rock at the outcrop but is reported to be cut by it in the mine workings. As in the Alvarado and Cane Springs mines the limestone has been largely replaced by wollastonite, diopside, and garnet, and by some sulphides and sulpharsenides. The gold occurs free and apparently in large part at least as an original constituent of the ore.

The ore apparently formed in shoots in the limestone for several hundred feet along its strike. At depth it is reported to have been faulted off, the ore abutting against "granite." Such a relation suggests that the contact is an intrusive rather than a true fault contact and that the ore has made out from this contact along the bed.

The ore milled from the deposit is said to have averaged about $20 per ton, principally

in gold with very little silver. A 50-ton mill on the property was operated for several years but was closed in 1904 and is in poor repair.

Gold Hill mine.—The Gold Hill mine is a contact deposit that differs considerably from those previously described. The rocks in the vicinity of the mine consist of limestone, shale, and quartz monzonite. The limestone is an irregular block, partly surrounded by quartz monzonite and cut by dikes of the same rock. The limestone has been greatly altered in part to a rather coarsely crystalline marble and in part (locally) to wollastonite, diopside, and other silicates. Along the eastern side, adjacent to the shale, it has been highly silicified and consists mainly of fine cherty quartz containing veinlets of coarser quartz and numerous vugs lined with quartz crystals. At the surface much of this material contains considerable iron and is jasperoidal. East of this silicified zone there is a body of altered black shale. The quartz monzonite outcrops to the west of the limestone and is present as irregular bodies in the limestone. This is the normal quartz monzonite of the region but is rather more porphyritic than that of much of the area.

The structure is typical of an intrusive contact, the sedimentary rocks now present apparently representing remnants of the sedimentary formation that covered the entire intrusive body at higher level. The silicified zone between the shale and limestone suggests alteration along a strong fissure or fault that can be followed for a considerable distance to the south.

The mine contains gold, copper, and lead-silver ores. The gold ores are similar to those of the Alvarado mine to the west, consisting of limestone that has been altered to wollastonite and diopside and that carries free gold as its valuable metal constituent. Some ore of this character was mined and milled at the Cane Springs mill, but its amount was apparently rather small. The copper ore occurs as a replacement of limestone along fissures—that thus far developed being to the west of the zone of cherty quartz.

Oxidation of the ore has been very complete, and it is impossible to identify the original metallic minerals. The oxidation products consist of abundant hydrous iron oxide and carbonates and arsenates of iron and copper. Most of the copper ore also carries some lead. The primary ores evidently were composed of sulphides and sulpharsenides of iron, copper, and lead. The copper ores commonly are rather rich in precious metals.

The report of the superintendent of the Western Utah Copper Co., dated September 30, 1909, places the actual copper ore in sight in the mine at 102,957 tons and the probable additional supply at 25,500 tons, a total of 128,457 tons. The report does not give the average metal content of this ore.

In 1917 the shipments of ore were 32,023 tons, of which 28,718 tons was copper ore, averaging 2.98 per cent copper and 4.33 ounces silver per ton, and 3,305 tons was lead-silver ore, averaging 5.62 per cent lead and 7.98 ounces silver per ton. As the work progressed there were indications that less ore of commercial grade would be available in the developed area than was estimated in earlier reports.

Lead ore is present in different parts of the mine. That treated at the Gold Hill smelter in the early days is reported to have been taken out near the outcrop of the ore body. The largest body developed is on the 300-foot level and below and has been prospected by a winze 45 feet below the 300-foot level. This ore is east of the quartz body.

The lead ore is of rather low grade but has an excess of iron, which ranges from 25 to nearly 40 per cent. Silica is usually not more than 15 per cent. The lead ore is of particular interest in that much of the lead is present as the hydrous ferric lead sulphate plumbojarosite. Probably a careful examination of the ore would show the presence of ferric lead sulpharsenates also.

Another feature of interest in this deposit is the abundance of the pale-green ferrous arsenate, scorodite, massive bodies of which outcrop in the gossan of the Gold Hill deposit.

REPLACEMENT VEINS IN SEDIMENTARY ROCKS.

Deposits have formed as replacements of sedimentary rocks along fissures at a considerable distance from an intrusive contact in many parts of the district.

The chief production from this type of deposits has been of lead-silver ores, though there has been some prospecting of gold-

bismuth ores. The main production is reported to have come from the limestone area forming the southern end of Clifton Mountain, in which numerous veins have been opened to a slight extent. The ore is all oxidized, is usually high in iron, and is reported to carry considerable silver. In several prospects in this area the rather unusual minerals plumbojarosite and beudantite were noted in considerable amount, but whether or not they constituted any large part of the ore mined was not learned.

To the west of Gold Hill post office is an extensive area of limestone in which are small bodies of intrusive rocks. Numerous veins in this area have been prospected, and a little ore has been shipped. Lead-silver is the main ore thus far developed.

In the limestone of Dutch Mountain are veins of lead-silver ore. The Spotted Fawn is said to be the most promising of those on the east side of the mountain, and is the only one that was examined by the writer. The ore occurs as a replacement of the limestone along a fissure. The surface ore is oxidized but apparently only to a depth of 30 feet. The primary ore is galena in a gangue of coarse quartz. Some ore is reported to have been shipped from this deposit.

In the area of limestone northeast of Clifton there has been some prospecting on veins in the limestone. The Success mine is said to have developed some zinc ore. This section of the camp was not visited by the writer.

A rather unusual type of replacement deposit in limestone in which the more important metals are bismuth and gold is being prospected by the Wilson Consolidated Co. about 1½ miles northwest of Clifton. The most prospecting has been on a vein that strikes east of north and dips westward. Some dikes of a highly altered intrusive rock near the deposit have no apparent close connection with the ore deposits.

The limestone adjacent to the fissure has been recrystallized to a rather coarsely crystalline carbonate. Considerable quartz is present, and locally a white micaceous chlorite is rather abundant. The primary metallic minerals are the sulphides of bismuth and copper, a tungsten mineral containing lead, probably stolzite, and possibly scheelite. Gold is probably also to be included among the primary minerals. The quartz and the metallic minerals replace the coarsely crystalline carbonate of the vein and were evidently deposited after the recrystallization of the limestone. The copper and bismuth sulphides have altered in part to carbonates and oxides, and some native bismuth is reported. The gold observed occurs as free gold closely associated with the bismuth sulphide. Tungsten was determined in but one specimen. A small fragment of a mineral that gave a reaction for tungsten also showed a reaction for lead, and it seems probable that the mineral is stolzite, though sufficient material for a more careful determination was not secured. A thin section from this specimen contained small grains of a mineral resembling scheelite. It seems probable that both stolzite and scheelite occur in small amounts in the ore. Selected specimens of the vein material contain a rather high percentage of bismuth. The vein as a whole, however, appears to have only a low content of this metal.

An occurrence somewhat similar to the deposit just described has been prospected on the lands of the Lucy L. Mining Co. between Clifton and Gold Hill. Bismuth (sulphide and carbonate) and native bismuth are present in coarse vein quartz. It is reported that "bunches" or "pockets" of ore contain considerable gold.

RELATIONS OF THE SEVERAL TYPES OF DEPOSITS.

The ore deposits of the district are believed to have been formed during one general period of mineralization. There is no evidence of mineralization previous to the intrusion of the quartz monzonite, and it probably took place at the time of and following the intrusion of that rock.

The aplitic and pegmatitic dikes in the quartz monzonite were, with little doubt, intruded shortly after the crystallization of the main body of intrusive rock. The close similarity of some of the metal-bearing pegmatitic veins to the barren pegmatitic dikes gives ample grounds for the belief that they are of common origin and that the productive veins represent a more advanced stage of differentiation. A similar gradation from the metal-bearing pegmatite veins to the quartz-tourmaline-carbonate copper veins, and from these to the quartz-

carbonate lead-silver veins, leads naturally to the belief that all are the results of the same general process.

The contact copper deposits, characterized by boron minerals, iron oxides, and magnesian silicates, are so similar in character to the tourmaline quartz veins that there can be no reasonable doubt that the solutions that formed the two had a common origin, and there can likewise be no doubt that the contact copper deposits at the south end of Clifton Mountain, where boron minerals were not noted but where other typical contact minerals such as garnet, diopside, and vesuvianite are present, are genetically connected with the intrusive rock in the same general manner as the tourmaline-bearing contact deposits. At the south end of Clifton Mountain the contact copper deposits show mineralogic gradations to the lead-silver replacement veins in many of which arsenic is an important constituent. In other parts of the district the relation between the contact deposits and the replacement veins can not be so definitely traced but may be logically inferred. The presence of tungsten in at least one of these veins indicates a relation between it and the other tungsten-bearing veins of the district.

The contact gold deposits are mineralogically typical of deposits formed in limestone adjacent to an intrusive body, but they differ rather materially from the other contact deposits in the district. Many of them contain considerable copper but no magnetite and specularite, almost no lead and zinc, and probably no boron. Molybdenum and arsenic, on the other hand, are present. In the Gold Hill mine the wollastonite gold ores are closely associated with copper and lead ores carrying a rather high percentage of arsenic, but the relation of the gold to the copper and lead was not clear.

The relation of the bismuth gold veins to the other deposits of the district was not ascertained.

Within a large area it is not to be expected that the ore-forming solutions will emanate from a common center, and it may be expected that the solutions in different areas will differ considerably in their initial composition, and as they progress from the point of origin, depositing some constituents and taking up others, will undergo a progressive and continuous change. Ordinarily it is not easy to distinguish effects due to original differences in solution from effects due to acquired differences or from effects due to the physical conditions under which the solutions acted; indeed, it is to be expected that all these factors were active and must be considered. Study of the mineralogic relations, however, may indicate which has been the most important.

All deposits, whether in quartz monzonite or in sedimentary rocks, that contain abundant boron minerals, iron oxides, copper and iron sulphides, and scheelite are confined to a rather definite zone and are either in or are closely associated with the intrusive rock. Some of the minerals are those that are generally recognized as characteristic of high temperature and pressure. Quartz-carbonate veins are present within this area, but they are not abundant.

In the monzonite outside of this area quartz-carbonate-lead veins are abundant and in the limestone are replacement lead veins. These do not contain minerals especially characteristic of high temperatures and pressures.

The contact gold veins, from their relation to the main body of intrusive rock and their mineral composition, are believed to have been formed under conditions of less temperature and pressure than the contact deposits containing boron minerals, iron oxides, and copper, but probably at higher temperature and pressure than the lead-silver veins. In metal content they are related to the copper deposits in carrying considerable of that metal but differ in the absence of tungsten; wollastonite and diopside are the principal gangue minerals. Their chief resemblance to the lead-silver veins is that both contain arsenic minerals, and their close association in the Gold Hill mine suggests that they were formed under nearly similar conditions.

The above relations may be explained as follows: After the intrusion and partial crystallization of the quartz monzonite the rocks of the area were fissured so as to permit the passage of solutions from deep-seated sources. When these solutions were at high temperature they deposited feldspar, tourmaline, magnetite, specularite, and kindred minerals and naturally became depleted in the elements forming those minerals. At the same time the solutions dissolved calcium and sodium from the wall rock and naturally became richer in these elements. At greater distances the temperature and pres-

sure were reduced and carbonates, galena, and other minerals were deposited and of course the nature of the solutions was still further changed. As the whole system cooled heat and pressure became less in the zone where previously minerals characteristic of high temperature and pressure had been deposited, and the carbonate quartz veins could be deposited in association with tourmaline quartz veins. That there are so few of these carbonate quartz veins in the central area seems to indicate that the principal mineralization occurred before the system had cooled to any great extent, and that those that do exist record the dying phases of mineralization.

If these conclusions are correct the action in this district differed considerably from that at Dolores, Mexico, where Spurr, Garry, and Fenner have shown that there was a progressive change in the original character of the mineralizing solutions, and also differed somewhat from that in the Ely, Nev., district where Spencer finds a sudden and marked change in the mineral solution near the close of the period of primary mineralization.

The writer does not maintain that no changes in the initial character of the ore solutions resulted from differentiation, but only that the major changes in the deposits were due to the physical conditions at different points and that the marked changes in the composition of the solutions were in part at least due to the precipitation of certain elements and the solution of others in their place.

WILLOW SPRINGS DISTRICT.

The Willow Springs district is in the higher parts of the Deep Creek Range, a few miles south of Overland Canyon. The higher portions of the range were covered with snow at the time of the writer's visit, and this district was not examined. The rock formations are said to consist of limestones and quartzites with some slaty shales and a few "porphyry" dikes. The ores occur as replacement veins in the sedimentary rocks. Both lead and copper ores are present, but there has been little production and comparatively little development in this district.

DRY CANYON.

Dry Canyon is on the east side of the Deep Creek Range south of the Overland Pass. This district was not visited by the writer. The mineralization is said to consist of replacement veins in limestone in part at least associated with "porphyry" dikes. The principal metals are lead and silver. A few small shipments of ore have been reported.

GRANITE CREEK DISTRICT.

The Granite Creek district is on the east side of the Deep Creek Range, about 12 miles southwest of Callao. Granite Creek, flowing from the higher parts of the range, supplies excellent water, and the higher parts of the range contain considerable timber.

The mineralized area is in the schist quartzite rocks which form the base of the sedimentary series exposed in the range. The schists, for the most part, at least, have resulted from the alteration of sandstones and shales. In some of the beds pebbles of quartz and a granitic rock can be detected, though they have been drawn out into lenticular form and metamorphosed to a considerable extent. Some "beds" of a green hornblende rock that seem to conform to the bedding of the sedimentary rocks may be of intrusive origin.

North and west of the schist area the large Ibapah stock of coarse-grained biotite granite has been intruded into the sedimentary series. (See p. 472.) Dikes of the granite can be traced directly from the main mass into the sedimentary series and dikes of finer-grained rock having a composition similar to that of the main mass are present in the schist series at some distance from the contact. Pegmatite dikes are present in the granite and also in the schist, and several dikes of rather coarse-grained rock of dioritic composition were noted in the schist.

Veins of coarsely crystalline quartz are common in the schist. Some veins of a fine cherty quartz that appear to have formed in part at least by the replacement of the rock adjacent to the fissures carry small amounts of pyrite, pyrrhotite, magnetite, galena, sphalerite, and chalcopyrite and are said to contain gold and silver. There has been some prospecting of the veins and a small production, but, except for a few small rich pockets, the ore has been of low grade, and the indications for large bodies even of such ore can not be said to be promising.

JOHNSON PEAK OR TROUT CREEK DISTRICT.

The Trout Creek district is located on the east side of the Deep Creek Range, about 3 miles south of Granite Creek. Trout Creek, which comes from the higher parts of the range, furnishes a supply of excellent water, and the higher parts of the range contain considerable timber.

The sedimentary rock is the same schist quartzite formation as that at Granite Creek, except that beds several hundred feet lower are exposed at Trout Creek. These include several strata of impure limestone. No intrusive rocks were observed in or near the deposits.

The schist series has been cut by several fissures along which there has been alteration of the rocks, especially the limestones. Tremolite and other silicate minerals were noted in these alteration zones. Lead and zinc minerals are both present in small amounts at several prospects.

The principal development has been on the north side of Trout Creek near the base of the range. At one point (in 1912) an incline has been sunk on a fissure developing a deposit of zinc. This was not examined in the underground workings, but the vein is said to be 2 to 4 feet wide and has been drifted on for some distance. The ore on the dump consisted of a dark sphalerite with a gangue of fluorite. Some of the zinc ore on the dump is of good grade but probably could not be shipped at a profit under ordinary conditions. Scheelite is reported to have been found in the district in 1916.

SPRING CREEK DISTRICT.

The Spring Creek district is on the west side of the Deep Creek Range, about 15 miles south of the settlement of Ibapah. The streams from the high range furnish a supply of excellent water and there is also good timber on this part of the range.

GEOLOGY.

The sedimentary rocks in the main mineralized area near the Queen of Sheba mine are quartzites, though limestones are present along the western foothills of the range south of Fifteenmile Creek. The quartzite is commonly a rather fine-grained reddish-brown rock. Occasionally there are beds that contain small pebbles. The general strike of the beds is about with the range, a little east of north, with a dip to the west at an angle around 30°. Near the granite the strike and dip of the quartzite are variable. To the north of the quartzite is the Ibapah mass of granite. This is the coarse granite already described. There are many dikes of granite in the quartzite near the main granite mass. Near the quartzite the granite appears to be rather fine grained and slightly more basic.

There are numerous dikes of coarse pegmatite composed essentially of quartz, feldspar, and muscovite with occasionally a little tourmaline. In addition to the true pegmatite dikes there are numerous dikes or veins of coarse pegmatitic quartz.

ORE DEPOSITS.

The principal ore deposit thus far developed is that of the Queen of Sheba mine. The ore body occurs in quartzite near the granite contact. The quartzite for some distance from the contact is apparently underlain at no great distance by the granite. The main fissure strikes about N. 60° E. and dips rather steeply to the southeast. The vein ranges in thickness from a few feet to 15 feet or even a greater thickness. The fissure filling is mostly quartz though very often the quartz gives place to a pegmatite composed essentially of quartz, orthoclase, albite, and muscovite. At other points the vein filling is of a much finer grained rock resembling an aplite in appearance and composed of essentially the same minerals as the pegmatite with pink garnet as a rather abundant accessory mineral. Locally the vein material contains some biotite. The different types of vein material grade into each other and are evidently of a common origin. The ore consists of a porous vuggy quartz usually containing considerable hydrous oxide of iron with some manganese. A little galena is occasionally present and pyromorphite was also noted in the ore. Stains of copper carbonate are also occasionally seen. The gold is free in the oxidized portion of the vein, though it may originally have been contained in sulphides. Where the porous quartz changes in character to a more massive type or when the feldspathic constituents come in, the metal content quickly decreases. In the lower workings (in 1912) the vein passes from the quartzite into granite

and essentially at the contact of these rocks the character of the vein filling in the ore shoot that was being followed changes from quartz to a feldspathic rock and ceases to be ore. Whether this is a local change such as occurs at higher levels or whether the vein filling in the granite will be uniformly feldspathic can be determined only by additional development.

It may be noted in this connection that in the very similar deposits in the Park Valley district (see p. 498) the ore occurs in veins inclosed in the granitic rock.

The outcrop of the vein is rather prominent and it is reported that good ore was present practically at the outcrop. The main vein is cut by cross breaks that have brecciated the rock but usually have resulted in but slight displacement. Commonly there is some gouge matter on these breaks.

The largest ore shoots in the mine are associated with the cross breaks, suggesting that these have influenced the formation of the shoots. The loose brecciated rock along these breaks furnishes the easiest course for the passage of solutions, and as the brecciation occurred after the formation of the veins, the rich shoots may most naturally be attributed to enrichment by descending solutions. There was, however, no opportunity to ascertain by a study of primary ore the changes due to oxidation. Moreover, the reported presence of good ore at the outcrop indicates that there has been no extensive downward leaching.

The deposit had been followed down the dip from the outcrop for about 500 feet in 1912. It is reported[1] that considerable additional development has been done since then, and some metal produced. The total bullion produced is said to have averaged about 0.650 fine.

The apparent gradation from pegmatitic rock into quartz veins containing metallic constituents naturally suggests that the primary deposits were formed by differentiation of the granitic magma. Very similar deposits that are believed to have a similar origin occur in the Park Valley district (see p. 498), and Spurr[2] has described similar deposits in the Silver Peak district, Nev., which he ascribes to similar differentiation.

[1] Reagan, A., The Deep Creek gold mining district: Min. and Eng. World, vol. 41, Dec. 12, 1914.

[2] Spurr, J. E., Ore deposits of the Silver Peak quadrangle, Nev.: U. S. Geol. Survey Prof. Paper 55, p. 122, 1906.

The ore from the mine has been treated at a mill on Fifteenmile Creek, to which it was transported over a gravity tram about a mile long.

SILVER ISLET RANGE.

By B. S. Butler.

GENERAL FEATURES.

The Silver Islet district is in the range of the same name, near the western border of the Great Salt Lake desert. The nearest railroad point is Wendover on the Western Pacific, about 15 miles to the southwest. Timber is almost totally lacking on the range, and water for drinking and cooking was in 1912 hauled from Wendover. Brackish water is obtained by sinking wells into the alluvium at the base of the mountain.

The district was organized in 1872. Nothing is known of its early production. The deposit in the Carrie Mack property, said to have been discovered by a sheep herder named McKeller about 1902, shipped some lead ore by wagon 35 miles to Lucin on the Southern Pacific Railroad. Production was first reported from Silver Islet Range to the Geological Survey in 1908. Shipments increased after the building of the Western Pacific Railroad. The total output of the district from 1908 to 1913, inclusive, aggregates 760 tons of ore containing $809 in gold, 110,614 ounces of silver, 57,535 pounds of copper, and 414,339 pounds of lead, valued in all at $90,219.

The relatively low range rises abruptly from the flat alkali desert which nearly surrounds it. Its general trend is northeast. About 10 miles northwest of Wendover it is separated into two parts by a low pass whose summit is only a few hundred feet above the level of the desert.

GEOLOGY.

SEDIMENTARY ROCKS.

The rocks of the range, so far as observed, are sedimentary with the exception of a few small dikes. Limestones make up by far the greater part, though a considerable thickness of conglomerate and quartzite is exposed at the north end of the portion of the range south of the low pass.

The rocks of the southern portion of the range were not examined except as they could

be seen from the road leading to the mines, and no fossils to indicate their age were obtained.

Fossils collected at different horizons in the northern part of the range were submitted for paleontologic examination to Edwin Kirk, who reports as follows:

No. 173. East side of Silver Islet. Second canyon north of Morrison camp:

Dalmanella pogonipensis Hall and Whitfield.
Clitambonites? near C. ionensis Walcott.
Straparollus? sp.
Maclurea? annulata Walcott.
Eccyliopterus michleranus? Hall.
Bathyurus sp.
Leperditia bivia White.

No. 174. East side of Silver Islet. Third canyon north of Morrison camp:

Dalmanella cf. D. perveta Hall.
Bucanella n. sp. similar to B. nana Meek.
Eccyliopterus sp.
Lophospira n. sp.
Homotoma sp.
Coleoprion sp.
Cyrtodonta n. sp.
Several undescribed species of Ostracoda, of the genera Leperditia, Leperditella, and Aparchites.

The lots listed above fall within the upper part of the Pogonip limestone. They may be correlated with the lower part of the Simpson formation of Oklahoma, which is held to be basal Ordovician by Ulrich. This general faunal aggregate is widely distributed throughout the West and maintains a fairly uniform character.

It is evident that the rocks of the northern part of the range are of Ordovician age with possibly older rocks to the north of the point where they were examined.

In the atlas accompanying the report of the Fortieth Parallel Survey the range is given as Carboniferous. No statement was found in the text of that report to indicate on what evidence this determination was based, but it appears probable that the rocks of the southern and more accessible portion of the range were determined by the geologists of that survey to be Carboniferous and that the more remote portion, not visited by them, was inferred to be Carboniferous also.

IGNEOUS ROCKS.

The observed igneous rocks are confined to a few dikes. One near the Morrison group is a dark medium-grained rock in which biotite crystals are conspicuous. In the hand specimen the rock is suggestive of the lamprophyric type. Under the microscope it is seen to be composed essentially of plagioclase, orthoclase, biotite, hornblende, and some quartz, with magnetite and apatite as accessory minerals. The rock has undergone considerable alteration, calcite, chlorite, and epidote being rather abundant secondary minerals. Plagioclase is considerably more abundant than orthoclase, and hornblende and biotite are approximately equal. In mineral composition, therefore, the rock is intermediate between kersantite and camptonite. Another dike, exposed near a prospect on the west side of the range, is apparently similar in mineral components but contains a much larger percentage of the feldspar and a correspondingly smaller percentage of the ferromagnesian minerals. These last are too highly altered for their original form to be definitely determined, but both biotite and hornblende were present in the original rock. The rock is dioritic in composition and may be classed as diorite porphyry.

STRUCTURE.

The sedimentary beds of the range strike about northeast and dip northwest and are cut by numerous faults. At the south end of the portion of the range north of the pass a strong northeast-trending fault that cuts the limestone is marked by a zone of highly brecciated rock 20 feet or more in width. In places the slickensided and polished walls of the fault stand up as a prominent cliff. The displacement was not determined but is apparently considerable; for east of the fault the sedimentary beds are much flatter than to the west and in some places a gentle easterly dip replaces the prevailingly westerly one.

The limestone is also cut by a series of fissures striking nearly north and dipping steeply west. The fissures are east of the fault and appear to be cut off by it; at least they have not been noted west of the fault. The fissures are also cut by faults with small displacement, one of which, revealed in the development of an ore body on the Morrison group, has a throw of approximately 20 feet.

ORE DEPOSITS.

In the deposits in the Morrison group the ore bodies occur as lenticular bodies in the fissures, "pinching" and "swelling" along both the strike and the dip. Bodies of ore extending out from the fissure along certain

beds of limestone that are so characteristic in most of the deposits in limestone are not present in this deposit. The width of the vein differs greatly from place to place, widening from a mere stringer to several feet and again "pinching" to a stringer.

The original filling of the fissures apparently consisted mainly of quartz with sulphides of lead, copper, and iron, and some antimony mineral, possibly jamesonite. Silver is an important constituent. The sulphides to the present depth of development have been largely oxidized to carbonates of lead and copper hydrous oxide of iron together with rather abundant bindheimite.

The principal value of the ore is in its lead and silver, though some of it carries several per cent of copper. The ore thus far extracted is of high grade, carload lots averaging as high as $120 per ton.

Other developments on the east side of the range have yielded comparatively little ore. They were not active at the time of visit and could not be examined.

On the west side of the range a deposit that has been considerably developed occupies a fissure striking almost north and standing nearly vertical. Not far from the prospect a nearly vertical dike of diorite porphyry several feet thick, that apparently cuts the ore vein, can be traced northwest for several hundred feet. The limestone is recrystallized in the vicinity of the dike, and for 10 to 12 feet from it has been rather highly silicified and colored red by iron. Under the microscope the silicified rock is seen to be composed of quartz, calcite, and abundant foils of muscovite. The original vein filling in this fissure, as in those on the east side of the range, is quartz and the metallic sulphides. The property was idle at the time of visit and the workings were not examined, but so far as could be judged from an examination of the dump oxidation has been rather complete to the depth of present development.

The genesis of the deposits of the district is not strongly indicated from the evidence collected. Many of them are associated with dikes, but the dikes are apparently of later age and indicate no close genetic relation.

There appears to be no reason, however, for considering the origin of these deposits to be different from that of similar deposits that are definitely related to bodies of intrusive rock.

LAKESIDE DISTRICT.

By V. C. Heikes.

The Lakeside district is in Tooele County, in a low range skirting the Great Salt Lake. Dell is the railroad point on the Western Pacific Railroad. The district was organized March 25, 1871, and was the scene of some mining excitement [1] from 1871 to 1874, since which time little has been done. A number of claims, about 2 miles from the lake and 500 feet above it, are said to have shipped—but not profitably—a large quantity of lead ore containing silver in early days.

NEWFOUNDLAND DISTRICT.

By V. C. Heikes.

The Newfoundland district, in Box Elder County, is in a small mountain range in a marshy desert 6 miles south of Newfoundland station on the Southern Pacific Railroad. It was organized in 1872. Huntley says [2] that many locations had been made but few claims patented prior to 1880; that the formations comprise both sedimentary rocks and some porphyry, and that the veins are narrow (18 inches) and contain milling ore. No production has been reported

PILOT RANGE.

By B. S. Butler.

TOPOGRAPHY.

The Pilot Range (Ombe Range) trends a few degrees east of north and is about 30 miles in length and 4 to 5 miles in width. Its highest point is Pilot Peak, which reaches an elevation of approximately 10,000 feet. Its northern portion, which is 2,000 to 3,000 feet lower, slopes steeply eastward to the Great Salt Lake Desert and with relative gentleness westward to the Tecoma Valley.

LUCIN DISTRICT.

LOCATION.

The Lucin district is in the Pilot Range, on the boundary of Utah and Nevada, a few miles south of the Union Pacific Railroad. The nearest station on the main line is Tecoma, Nev., which is 7 to 10 miles from the mines by wagon road; but shipments are made from

[1] Huntley, D. B., Precious metals: Tenth Census U. S., vol. 13, p. 454, 1885

[2] Idem, p. 451.

the base of the range, to which a spur from the main line has been constructed. The ores of the Copper Mountain mine are transported from the mine to the terminal of this spur by an aerial tram.

HISTORY AND PRODUCTION.

By V. C. Heikes.

The deposits of the Lucin district were discovered in the summer of 1868, and the district was organized September 2, 1872. The mines are in the Lucin Range of mountains, on the dividing line between Utah and Nevada, but are all on the Utah side, in Box Elder County.

A smelting furnace was erected in 1871 at Buel City, at the edge of the foothills among which are the mines. Copper[1] was first discovered in native form, the red and black oxides and green and blue carbonates. Subsequently, galena was found in considerable quantity. According to Huntley[2] all the early production was prior to 1876. He says:

The English Tecoma company, or the Tecoma Mining Co. of Utah (Ltd.), owns several claims, two of which, the Gladstone and the Shanly, were patented. * * * This was the same company that bought the Flagstaff and the Last Chance (in Salt Lake County). About 1,000 tons of low-grade ore (30 per cent lead and from 10 to 25 ounces silver) was extracted, which was shipped to the company's furnace at Truckee, Cal., about 500 miles distant. The total cuttings aggregated possibly 1,500 feet.

The American Tecoma company, or the Tecoma Mining Co., owned eight patented claims. A furnace was erected in 1871; and while the mines were looking well the property was sold to Howland & Aspinwall, of New York, in 1872. The latter owners extracted several thousand tons of ore (averaging about 35 ounces silver and 45 per cent lead) from two well-defined surface bodies and shut down in 1875 or 1876. The claims have been idle since. In the lower parts of the ore bodies much wulfenite was found.

In 1874 about forty tons of horn-silver ore were collected on the Black Warrior claim from surface deposits by gopher-hole work, which were said to have yielded $16,000.

Between 1886 and 1894 the copper properties were vigorously worked and subsequently sold to the Salt Lake Copper Co., which erected, in 1893 and 1894, very extensive electrolytic works in the northern part of Salt Lake City. This plant shipped in October, 1894, two carloads (61,832 pounds) of ingot copper, said to have been the first fine copper shipped out of Utah. Some of the ores treated were from the old Copperopolis mine (in the Tintic district), which was purchased by the company in 1894 and thereafter known as the Ajax Mining Co. By the end of 1894 the electrolytic plant and property were in the hands of a receiver and considered a complete failure.

Statistics prior to 1876 are not available, but estimates based on the reports of Huntley[2] and Murphy[3] and information from former owners of the property in the district are tabulated as follows:

Metals produced in Lucin district, 1870–1917.

Period.	Ore (short tons).	Gold.		Silver.		Copper.		Lead.		Zinc.		Total value.
		Fine ounces.	Value.	Fine ounces.	Value.	Pounds.	Value.	Pounds.	Value.	Pounds.	Value.	
1870–1905..	29,864	....	......	176,000	$220,282	1,675,200	$237,835	3,720,000	$219,720	....	......	$677,837
1906–1913..	99,748	27.29	$563	21,886	12,387	12,027,418	1,767,346	177,481	7,973	....	......	1,788,269
1914–1917..	22,883	77.14	1,595	27,250	20,815	2,874,703	697,077	851,641	67,063	34,680	$3,537	790,087
	152,495	104.43	2,158	225,136	253,484	16,577,321	2,702,258	4,749,122	294,756	34,680	3,537	3,256,193

GEOLOGY.

The rocks of the Pilot Range consist of sedimentary and igneous formations, the latter consisting of both intrusive and extrusive rocks.

SEDIMENTARY ROCKS.

In the southern part of the Pilot Range, according to Hague,[4] quartzite is the prevailing rock, Pilot Peak being composed entirely of this rock and a total of 6,000 to 7,000

[1] Murphy, J. R., Mineral resources of the Territory of Utah, Salt Lake City, 1872.

[2] Huntley, D. B., op. cit., p. 484.

[3] Op. cit., pp. 41–42.

[4] Hague, Arnold, and Emmons, S. F., Descriptive geology: U. S. Geol. Expl. 40th Par. Final Rept., vol. 2, p. 496, 1877.

feet being exposed. The extreme south end of the range is composed of limestone. North of Patterson Pass limestone occupies the eastern portion of the range for several miles, and still farther north in the principal mineralized area it is the predominant sedimentary rock. Quartzite interbedded with shale and limy shale is present on the east side of the range for several miles north of Patterson Pass.

In the vicinity of the mines several thousand feet of heavy-bedded limestone is apparently overlain by fully as great a thickness of a siliceous series of quartzite, conglomerates, and shale with interbedded limy shale. This siliceous series is also present south of the main mineralized area.

Hague [1] states that near the northern end of the range and at the eastern base Tertiary beds outcrop that "consist mainly of white, thinly bedded calcareous and siliceous shales, remarkably fissile and frequently bituminous." From their character they are thought to be equivalent to the Green River Eocene, though fossils were not found in them. They have been deformed, but what are believed to be late Tertiary beds at the north end of the range lie nearly horizontal. These beds, according to Hague, consist of "fine siliceous rhyolitic material interstratified with occasional fine sands."

Hague has provisionally correlated the quartzite with the Weber quartzite of the Wasatch Range. He states, however, that some of the quartzite has undergone considerable metamorphism and may be older than the Weber quartzite.

The limestones at the south end of the range are referred by Hague to the "Upper Coal Measures." They yielded *Productus punctatus* and *Spirifer cameratus*.

The entire sedimentary series at the north end of the range is of Carboniferous age, consisting of Pennsylvanian and probably upper Mississippian.

Fossils were collected from several horizons south of the main east-west fault. From about the central portion of the limestone as exposed G. H. Girty determined *Zaphrentis multilamella?*, *Spirifer agalaius?*, *Eumetria?* sp., and *Bellerophon* aff. *B. percarinatus*. Mr. Girty says that he is uncertain of the position of this fauna in the section. A somewhat similar fauna in the Oquirrh Range appears to be at the base of the Pennsylvanian or at the top of the Mississippian.

Several hundred feet above the base of the shale-quartzite series, a collection which Mr. Girty regards as upper Mississippian yielded *Lingulidiscina newberryi* var. *marshallensis?* and *Martinia* sp. A fossil from still higher in the series was determined by Mr. Girty to be *Fusulina* aff. *F. cylindrica* and of Pennsylvanian age.

Near the eastern base of the range, fossils were collected that were identified by Mr. Girty as crinoidal fragments, *Martinia* sp., and *Spirifer* aff. *S. cameratus* and are regarded by him as upper Mississippian. It seems probable that there is a strong fault in this part of the range, though none was recognized in the hasty traverse made.

The only collection from north of the main east-west fault was made near the base of the limestone cliff about due east of the terminal of the ore tram. *Fusulina cylindrica*, *Rhombopora lepidodendroides?*, and *Bellerophon* sp. were determined and are considered by Mr. Girty to be of Pennsylvanian age. In the field this horizon was thought to be approximately equivalent to that from which fossils were collected in the limestone south of the fault, but the fossil evidence indicates that it is considerably higher.

IGNEOUS ROCKS.

INTRUSIVE ROCKS.

According to Hague, the largest body of intrusive rock in the range is exposed in Patterson Pass. It has a width from north to south of about 2 miles and extends entirely across the range. North of Patterson Pass less extensive bodies of the granite outcrop on both the east and west sides of the range—for instance, on the east side, on the Copper Mountain property, southeast of the lower tunnel, which is driven in granite for a part of its length; and on the west side in numerous places along the foothills.

Hague [2] gives the following description of the granite at Patterson Pass:

This granite is a medium-grained rock, somewhat friable in texture and of a reddish-gray color, derived from

[1] Op. cit., p. 458.

[2] Idem, p. 465.

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an admixture of both red and white feldspars. The mineral constituents are chiefly quartz in small translucent grains, associated with both microcline and triclinic feldspars. Mica in thin brown flakes, frequently adhering to the broader faces of the feldspar, is present but in subordinate amounts. The white feldspars are frequently an inch in length, forming a strong contrast to the smaller but more abundant red crystals.

Similar granitic rock is exposed in the north end of the range. The orthoclase is approximately equal in amount to the plagioclase, which has a composition varying little from andesine. The dark silicates are commonly largely altered to a chloritic material that has apparently been derived principally from biotite, though perhaps to some extent from hornblende. Quartz is rather abundant, in places probably amounting to 20 per cent. The rock is locally called granite, but quartz monzonite is a more exact name.

On the east side of the range the intrusive rock is cut by dikes that differ from the main body of the quartz monzonite in containing a much larger amount of dark mineral (hornblende, in the sections examined) and more plagioclase, which is also of more basic composition. Quartz is present but not in large amount. The more basic of these dikes have essentially the composition of quartz diorite, and several of them have distinctly lenticular forms that strongly suggest basic segregations.

The sedimentary rocks are cut by more siliceous and more basic dikes. Typical diabase dikes, composed essentially of plagioclase and pyroxene with minor amounts of magnetite and apatite, are present in the workings of the Copper Mountain mine and in the granite north of Tecoma Hill and probably at other points. Siliceous dikes were noted in the limestone of Tecoma Hill and are doubtless present at other localities. The rock is light gray to nearly white and usually is porphyritic. The phenocrysts are orthoclase and quartz inclosed in a fine groundmass of orthoclase and quartz, of which the orthoclase is considerably the more abundant in the specimens examined. Dark silicates are almost entirely absent, though small areas of quartz carbonate and a little chlorite and muscovite possibly represent altered biotite. On weathering, the phenocrysts of orthoclase are readily removed, giving the exposed surface of the rock a characteristic pitted appearance. On the north side of Tecoma Hill numerous aplitic dikes in the limestone near the granite contact are composed of an intergrowth of quartz and orthoclase and are usually of medium grain. Many of the fissures containing aplitic dikes also contain a vein of coarse quartz with sulphides.

EXTRUSIVE ROCKS.

The extrusive rocks are confined mainly to the north end of the range. According to Hague both rhyolite and basalt flows occur, the rhyolite being the earlier. The rhyolites are glassy rocks containing phenocrysts of quartz and sanidine, and the basalts are holocrystalline porphyritic rocks with rather abundant feldspar phenocrysts.

Hague [1] gives the following analyses of the basalts:

Analyses of basalt from Pilot Range.

[R. W. Woodward, analyst.]

	1	2
Silica	54.80	54.79
Alumina	17.58	17.59
Ferric oxide	.97	.94
Ferrous oxide	8.84	8.85
Manganous oxide	Trace.	Trace.
Lime	8.22	8.13
Magnesia	4.47	4.54
Soda	3.14	2.97
Potassa	1.16	1.16
Water and carbonic acid	.94	.98

Hague states that there is a small outflow of gray rhyolite along the east base of Pilot Peak.

RELATIONS OF IGNEOUS AND SEDIMENTARY ROCKS.

That the quartz monzonite of the Lucin district is clearly intrusive in the Carboniferous rocks is shown by dikes of a rock closely resembling the quartz monzonite that cut the sedimentary rocks, by the presence near the quartz monzonite contact of rather abundant aplitic dikes that are evidently offshoots of the main mass, and locally by the presence of contact silicates in the limestones adjacent to the contact. The igneous rock is in contact with different horizons in the sedimentary series over a thickness of at least several thousand feet, a relation readily and naturally accounted for if the quartz monzonite is intrusive in the sedimentary rocks. It seems likely that the bodies of quartz monzonite outcropping on the east and west side of the range are connected

[1] Op. cit., p. 500.

and that igneous rocks may be relatively more abundant at no great depth.

Some basic dikes cut the quartz monzonite, and it seems probable that the basic dikes in the sedimentary rocks are also later than the quartz monzonite, though positive evidence on this point is lacking. The siliceous porphyry dikes were not observed in the quartz monzonite and their relation to that rock is not known.

The flow rocks at the northern end of the range are later than the Carboniferous and earlier than the late Tertiary sedimentary rocks. They were not observed in contact with the intrusive rocks, and the relative ages of the two are not known.

STRUCTURE.

The structure of the district is too complicated to be thoroughly understood without detailed geologic work. Faulting has evidently been important; from the paleontologic evidence it has apparently been more important than general inspection would indicate. Folding has apparently played a minor part. Possibly, however, the rocks underwent broad open folding before they were faulted.

In the vicinity of Copper Mountain the rocks strike a little west of north and dip approximately 30° E. Whether their altitude is due to faulting and tilting or to broad open folding of which only one limb is exposed has not been positively determined. Indeed, the intrusion of the quartz monzonite may have exerted no small influence on the present position of the sedimentary beds.

A strong east-west fault that crosses the range south of Copper Mountain has caused the formation of a pass. Its throw has not been determined but was large. The siliceous rocks south of this fault do not extend north of it; those to the north seem to have been thrown down relatively to those to the south. A strong north-south fault extending north from the east-west fault along the crest of Copper Mountain is marked by a strong zone of brecciated and highly silicified rock. About 1,000 yards to the west another strong fault of similar trend extends south from the east-west fault and is possibly a continuation of the Copper Mountain fault, the two portions having been separated by the east-west movement. There are many minor faults in the district and probably some others of large displacement.

Fissures trending both east and north have been channels for ore solutions and for the intrusion of dikes

ORE DEPOSITS.

CONTACT DEPOSITS.

Contact deposits in the limestone adjacent to the quartz monzonite are accompanied by contact silicates, garnet, diopside, tremolite, and the like. These deposits have been prospected to some extent north of Tecoma Hill but have not yet been shown to be of commercial importance.

FISSURE DEPOSITS.

The replacement-vein type, which has furnished practically the entire output of the district, may be subdivided according to metallic content.

COPPER DEPOSITS.

The most important copper deposit—that of the Copper Mountain mine of the Salt Lake Copper Co.—is a replacement of limestone apparently chiefly along certain beds adjacent to a north-south fault zone. The sedimentary rock in the vicinity is limestone, and the only intrusive rock seen in the mine is a diabase dike 20 to 50 feet thick. The strike of the dike corresponds in a general way with that of the fault zone, and the intrusion apparently followed this plane of weakness. The accessible workings at the time of visit did not furnish conclusive evidence of the relation of the dike to the ore but indicated that it was intruded after the deposition of the ore. There has been movement along the fault zone, however, since the dike was intruded.

The ore thus far developed is entirely oxidized, consisting of hydrous oxides of iron, oxide of copper, "copper pitch" (a black substance containing copper and manganese), carbonates of copper, silicate of copper, and a large amount of a clayey mineral that is white to dark blue, according to the quantity of copper it contains. This material was reported by W. T. Schaller to be a hydrous aluminum silicate. Some specimens of the blue mineral approach the composition of chrysocolla. According to Ryan[1] some of the

[1] Ryan, G. H., Salt Lake Min. Rev., vol. 16, p. 20, 1914.

"talcy" material contains as high as 27 per cent of alumina. Irregular masses of cuprite are in places inclosed in this material, making a high-grade ore.

The character of the ore differs greatly at different points; for example, the southern part of the east ore body is mainly hydrous iron oxide which contains little copper but which is so high in iron that a large quantity has been shipped as fluxing ore. The northern part of the deposit contains much more copper and some of it is high-grade ore. For a considerable distance south of the known ore the outcrop of the fault zone is a highly silicified limestone stained with oxides of iron, in which no ore has been found.

The ore was doubtless formed by the oxidation of bodies of iron and copper sulphides, though neither was seen in the mine, the oxidation being unusually complete.

The ore body outcrops prominently, and much ore has been extracted by open-cut methods. The ore thus far mined has been in two bodies, separated by a relatively barren zone. The eastern wall of the eastern deposit is formed in part by the diabase dike. Prospecting east of the dike has failed to find ore in important amounts. Ore has been developed for 150 to 200 feet below the outcrop, but rather extensive prospecting at greater depth has failed to discover important bodies. In 1912 a tunnel which was being driven from the east side of the mountain 900 to 1,000 feet below the outcrop of the ore body, to prospect the supposed downward extension of the ore zone, had not encountered ore but had found a considerable body of quartz monzonite nearer to the ore zone than is apparent on the surface.

LEAD-SILVER DEPOSITS.

Several deposits in the district were worked mainly for their lead-silver content in the early days but are at the present in large part inaccessible. (See p. 489.) The Tecoma mine has been the most important producer of this type.

The sedimentary rock of Tecoma Hill is limestone, which, along the north side of the hill, has undergone some contact alteration and mineralization from the quartz monzonite there exposed. Dikes of siliceous granite porphyry cut the limestones. A strong one strikes generally east and apparently dips steeply south. The limestones are also cut by northeast-southwest fissures, some of which contain dikes.

The ore bodies could not be studied, but they apparently occurred as replacements of the limestone along the fissures, the main ore shoots being formed where certain beds of limestone had been replaced for some distance from the fissures.

The ore thus far extracted has been oxidized. It contained much iron and in places much wulfenite, the molybdate of lead. Hague[1] says:

> The molybdate of lead frequently forms so high a percentage of the ore as to interfere seriously with its treatment in the ordinary lead furnaces, rendering a modification of the methods employed very desirable. The crystallized wulfenite from the Tecoma mine occurs in large masses, the faces of individual crystals having been observed from an inch to 1½ inches in length. They possess a resinous luster, a lemon-yellow color, and are frequently transparent and exceedingly brittle. In size and brilliancy the finest specimens far surpass the famous wulfenite crystals from the limestones of Bleiberg in Carinthia. Associated with the wulfenite, adhering to the broad tabular faces, may occasionally be seen well-developed crystals of cerusite and anglesite (carbonate and sulphate of lead).

Plumbojarosite, a basic lead-iron sulphate, was collected from the dump of the Tecoma mine, but it is not known to what extent it was present in the ores.

In 1912 the Copper Mountain Mining Co. was extracting some oxidized lead ore north of the Copper Mountain copper mine from similar sedimentary rocks. The main development was in a fissure striking N. 60° W. and dipping northeast along which the mineralized band is practically continuous though not of uniform width, extending farther into some limestone beds than into others and being in places nearly cut out by coarse calcite which fills the fissures except for an inch or two in the hanging wall. The thickness of the ore varies from a few inches to 2 feet or more. Some copper ore has also been exposed. The output of lead ore from this part of the district has not been large.

In 1912 the Mineral Mountain Mining Co. was prospecting its property in the southern part of the district. A small amount of development was being done on other properties and some ore was shipped.

[1] Hague, Arnold, op. cit., p. 497.

GENESIS.

The present development of the district gives little clue to the origin of the ores. The Copper Mountain deposit is associated with a basic dike but affords no evidence of intimate genetic relation between it and the ore deposits. The same is possibly true of the siliceous dikes and the ore deposits in Tecoma Hill, their close association appearing to be due to the fact that both the ore solutions and the dikes entered the rocks along the same fracture zones.

The contact deposits that occur to a small extent in the limestone near the quartz monzonite are apparently genetically associated with its intrusion. This fact and the study of similar deposits whose relations are more apparent leads to the belief that all the ore deposits of the district are genetically associated with the intrusion of quartz monzonite. Heated solutions carrying the constituents of the ores rose along the fissures and deposited sulphides and other minerals in limestone beds favorable to replacement. These deposits were subsequently oxidized by descending solutions.

VARISCITE DEPOSITS.

Variscite, a hydrous aluminum phosphate ($AlPO_4.2H_2O$), occurs 5 miles northwest of Lucin and has been mined to some extent as a gem material.

According to Sterrett[1] the variscite occurs as balls, nodules, and irregular masses in a cherty breccia containing fragments of limestone.

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GROUSE CREEK RANGE.

By B. S. BUTLER.

LOCATION.

The Grouse Creek Range, in the northwestern part of the State, in Box Elder County, extends from a few miles north of the Southern Pacific Railroad (Lucin cut-off) to the northern boundary of the State, a distance of nearly 40 miles. Its southern and central portion lies between the Grouse Creek valley on the west and the Muddy Creek valley on the east. Farther north it merges with the Raft River Range.

GEOLOGY.

SEDIMENTARY ROCKS.

The lowest formation in the range observed by the writer is a thick series of hornblende and mica schist, which is overlain, in places at least, by a gneissic conglomerate, and this in turn by a series of impure limestones whose maximum observed thickness is about 100 feet. The limestone is followed by a series of sandy and shaly sedimentary deposits. Along the west side of the range a series of conglomeratic and sandy beds is overlain by light-gray tuffs. East of Grouse Creek the lowest beds exposed are a rather coarse conglomerate composed of pebbles of schist and quartzite. The pebbles are similar to the rocks exposed in the Grouse Creek Range. Overlying the conglomerate are thick beds of white tuff.

No fossils were found in the sedimentary series, but the highly metamorphosed character of the lower formations strongly suggests pre-Cambrian age and the less metamorphosed formations have been assigned to the same age (see Pl. IV), though they may prove to be younger. Hague[2] mentions finding an *Aviculipecten* in beds in the south end of the range, indicating the presence of Paleozoic rocks.

If the rocks of the main range are pre-Cambrian they contain more limestone than the corresponding rocks farther to the east. However, they seem lithologically to resemble the pre-Cambrian more closely than any younger rocks.

The conglomerates and tuffs along the western base of the range are regarded as of Tertiary age. Hague[2] refers them to the horizon of the Humboldt formation (Pliocene) from their general resemblance to the beds developed in the upper Humboldt Valley.

INTRUSIVE ROCKS.

The largest body of intrusive rock exposed in the range is near its southern end and is said to extend 6 to 7 miles from east to west

[1] Sterrett, D. B., U. S. Geol. Survey Mineral Resources, 1910, pt. 2, p. 894, 1911.

[2] Hague, Arnold, U. S. Geol. Expl. 40th Par. Rept., vol. 2, p. 420, 1877.

and about half that distance from north to south. Farther north a canyon southeast of Grouse Creek settlement has cut through the sedimentary rocks and exposed a body of intrusive rock, and other canyons are said to have done the same. The range may be underlain by a large body of intrusive rock, only comparatively small areas of which have been exposed.

The rock of the large mass in the southern end of the mountains varies considerably in composition. A large part of it is granodiorite or quartz diorite, but small bodies are probably true diorite, and others might be classed as quartz monzonite. The rock exposed at Red Buttes, southeast of Grouse Creek, is similar in composition to the larger body in the south end of the range.

Numerous pegmatite dikes composed of quartz and feldspar appear to grade into veins or dikes of pegmatitic quartz, many of which are large and can be traced for several thousand feet.

HISTORY.

By V. C. Heikes.

The Ashbrook district is in the northwest corner of Utah, where the Grouse Creek and Goose Creek ranges unite. It can be reached from Kelton, on the old line of the Southern Pacific Railroad, 55 miles to the east over a good wagon road, and from Burley, Idaho, on the Oregon Short Line, 83 miles to the north. The district is in an open rolling hill country, culminating here and there in high ridges and low mountain ranges. The mines are grouped within a circle a mile in diameter 7,000 feet above sea level. The first claim, the Homestake, was located August 19, 1873, and the district was organized July 1, 1874. The deposits have been worked at various times in a small way and are opened by a tunnel 1,400 feet long.

In 1891 the Lexington and Argenta claims of the Vipont group were worked under bond and lease. The Argenta claim, which was found to yield the richest silver ore, shipped nearly 26 tons, containing an average of 116.9 ounces of silver and 0.13 ounce of gold per ton, to the old Telegraph smelter in 1892 and a similar lot in 1893. The option was allowed to expire for want of sufficient funds for development.[1]

A milling plant, erected on the Vipont group in August, 1897, contained a Lewis roller mill, two amalgamating pans, and one settler, and treated, in 14 days, an average of 8 tons of ore per day, resulting in a bar of bullion weighing 99.5 pounds, of which one-twentieth was reported [2] to be gold and the remainder silver. In 1899 the mill equipment was enlarged by the addition of a double-deck Wilfley table.

PRODUCTION.

The only mining operations have been on the Vipont group, which, as already noted, yielded previous to 1899 some silver ore of shipping grade and milled some ore. From 1899 to 1904 685 tons of ore were mined. The production of the district during the seventies and eighties would aggregate as much as shown in the following table. The mines had been idle since 1904 but became active in 1917.

Production of metals in Ashbrook district.

Year.	Ore mined (short tons).	Gold.		Silver.		Total value.
		Fine ounces.	Value.	Fine ounces.	Value.	
1899....	225	37.17	$768	18,245	$10,947	$11,715
1900....	22	9.04	187	3,374	2,092	2,279
1901....	200	3.30	68	1,639	983	1,051
1902....	28	5.58	115	1,640	869	984
1903....	91	7.75	160	3,189	1,722	1,882
1904....	119	4.30	89	1,612	923	1,012
1917....	27	3.74	77	1,400	1,153	1,230
	[a] 712	70.88	1,464	31,099	18,689	20,153

[a] Yielded 125 tons of concentrate.

ORE DEPOSITS.

DEVELOPMENT.

Prospecting in the range began many years ago and has been intermittent to the present time, but no important production has resulted except in the northern extension of the range, near the Idaho line, where the Vipont mine, in the Ashbrook district, produced for a short time. At the time of visit (1915) prospecting was being carried on in the south end of the range, where scheelite deposits had been discovered by Frank Edison and were being prospected under the direction of George W. Riter, of Salt Lake City.

[1] Statement of G. Lavignino, Salt Lake City, March, 1915.

[2] Mining notes: Eng. and Min. Jour., Oct. 16, 1897.

TUNGSTEN DEPOSITS.

ROSEBUD CREEK DISTRICT.

OCCURRENCE.

The deposits of scheelite (calcium tungstate; CaO, 19.4 per cent; WO_3, 80.6 per cent) occur principally as a replacement of limestone. Associated with the scheelite is abundant quartz, epidote, chlorite, and muscovite, and lesser amounts of garnet and probably other silicates. Neither magnetite nor hematite was noted, and both are certainly notably scarce. Likewise, little sulphide is present though some galena has been found, and some of the limonite may have been derived from sulphide of iron. Barite was noted in several of the prospects and is apparently rather plentiful but was nowhere seen to be inclosed in scheelite nor scheelite in it.

The minerals replacing the limestone appear to have formed at essentially the same time. No other mineral has been observed inclosed in the scheelite, and it was possibly among the earliest to form, though the general relations indicate that the primary minerals were essentially contemporaneous.

At a few places the effects of mineralization extend along fissures a short distance into the intrusive body, but nowhere were they observed more than a few feet from the contact and nowhere did they change in character, indicating that the areas were within the influence of the limestone.

The deposits have undergone considerable oxidation. Among the secondary metallic minerals were noted cerusite, resulting from the alteration of galena, and vanadinite, possibly also a product of the oxidation of galena. Some of the scheelite is coated with a yellow material that is probably tungstate, though it was not obtained in sufficient amount for an accurate determination.

ORIGIN.

The minerals associated with the scheelite are the same as those present in other districts in the State where metal deposits occur as a replacement of limestone associated with intrusive bodies and where the evidence is pretty conclusive that the metals have been deposited from solutions coming from the intrusive rocks. The deposits differ in some of the associated gangue minerals from the scheelite replacement deposits of the Clifton district, but their general relations are similar and they are believed to have had a similar origin.

COMMERCIAL IMPORTANCE.

At the time of visit it had been shown that scheelite is present at numerous places along the contact. At no locality, however, had extensive development been made, and the exposures were not sufficient to warrant a prediction concerning the future possibilities of the deposits. At no place had material carrying more than a few per cent of scheelite been developed and most of the rock was very low in grade.

OTHER DEPOSITS.

North of the intrusive body at the south end of the range the quartz veins have been prospected at numerous localities but most extensively at the Mogul mine and at Red Buttes. At neither locality, however, were operations in progress at the time of visit, and few data concerning the deposits were obtainable. Specimens containing galena in a gangue of quartz and calcite were obtained on the dump of the Mogul mine and specimens composed of quartz and sulphides of iron and copper on the dump of the Red Buttes tunnels. Some of the black shale on the dumps of the Red Buttes tunnels was impregnated with iron sulphide. Both deposits are said to contain gold and silver.

The prospects north of Red Buttes were not visited. Considerable prospecting is said to have been done in the area between Red Buttes and the Vipont mine.

The deposits of the Vipont mine, in the Ashbrook district, are said to occur as a replacement of limestone associated with dikes of "quartz porphyry." The metallic minerals are sulphide of iron and lead, with arsenic and antimony minerals, in which the silver is said to be the most abundant. The oxidized ores are said to contain pockets of "chloride" and native silver.

RAFT RIVER MOUNTAINS.

TOPOGRAPHY.

The Raft River Mountains extend east and west for about 20 miles. South of the range is the broad Park Valley, from which the mountains rise to an elevation of about 2,000 feet. The streams south of the crest have carved the range into a series of ridges and

valleys, producing a topography which, as a whole, is not rugged when compared with that of other mountains of the State.

The range is sufficiently high to receive a rather heavy precipitation and the snow lingers till late in the spring, furnishing water to numerous streams.

PARK VALLEY DISTRICT.

By B. S. BUTLER.

The writer spent but one day in the Park Valley district, and the following notes are based on observations made during that time and information furnished by Messrs. T. W. Ireland and Harry Martin, in charge of the principal mines of the district.

GENERAL FEATURES.

The Park Valley district is in the northwestern part of Box Elder County, at the southern base of the Raft River Mountains. The district is about 25 miles northwest of Kelton, the nearest railroad station on the old line of the Union Pacific Railroad.

Though there are no large streams, sufficient water for milling is furnished by the streams from the mountains. Coal has been generally used as a fuel for power purposes, but the long haul has made it expensive. The Susannah mine has employed gasoline power.

HISTORY AND PRODUCTION.

By V. C. HEIKES.

Golden, the principal camp of the district, is on the southern slope of the Raft River Range. A company was formed in 1896 to operate the Century property and was the beginning of activity in the district. Shortly after a Crawford amalgamation mill of 10 tons daily capacity was erected and considerable gold bullion 0.954 fine was recovered. This mill was eventually discarded and a new one, with sixteen 1,000-pound stamps and five Wilfley concentrators, was erected. About 75 per cent of the assay value of the ore was recovered by amalgamation and 15 per cent by the recovery of lead concentrates. This mine ceased producing about 1905 on account of the exhaustion of the better grade of ore that had been developed and the necessity of more development, which has been performed from time to time up to 1913. About $400,000 has been produced in gold, silver, and lead and $35,000 paid to the mine stockholders.

To the west the extension of the Century vein was opened in the Susannah property. The high-grade gold ore was shipped and the second-class ore was treated in a 10-foot Lane slow-speed roller mill, which was constructed in July, 1909. Since then a small amount of gold bullion has been produced every year.

GEOLOGY.

SEDIMENTARY ROCKS.

The sedimentary rocks in the vicinity of Golden, near the west end of the range, where they were examined by the writer, consist of a series of quartzites and schists, both highly metamorphosed. The quartzite shows the development of muscovite and a schistose cleavage and the schist is typically a dark biotite schist, but there are all gradations between the two. The formation, several thousand feet of which is exposed, is evidently a metamorphosed series of interbedded shales and quartzites. No other formation is exposed south of the divide in the vicinity of Golden, and as the range was not examined to the east, where later rocks are apparently present, it is not possible to give its exposed thickness. No fossils were collected from the sedimentary series and its age is therefore not known, but as its general character and appearance are similar to those of the pre-Cambrian of the Wasatch Range, it is provisionally considered of that age.

IGNEOUS ROCKS.

Igneous rocks were observed only in the immediate vicinity of Golden, but granite is reported to outcrop in Pine Canyon, several miles to the east.

The main intrusive body consists of coarse-grained porphyritic granite composed mainly of quartz and feldspar and some biotite. The porphyritic crystals are microcline and inclose small crystals of acidic plagioclase. Crystals containing many foils of sericitic mica appear to be plagioclase. The groundmass of the rock is an intergrowth of quartz and orthoclase, with foils of biotite and muscovite.

Near the contact with the sedimentary rocks the granite has a schistose or gneissic structure.

Both the granite and the sedimentary rocks adjacent to the granite are cut by numerous

pegmatite dikes, which vary greatly in size and composition. They are composed essentially of quartz and orthoclase, but they grade from rock in which feldspar is abundant to pegmatitic quartz veins from which it is entirely absent.

In many dikes the feldspar is concentrated near one or both walls and the quartz in the center or adjacent to one wall. In such dikes there is no definite boundary between the feldspathic portion and the quartz portion. Many such dikes contain small amounts of sulphide, which was one of the latest minerals to crystallize. The order of crystallization of the minerals was first quartz and feldspar, later quartz alone, and finally sulphides.

RELATIONS OF SEDIMENTARY AND IGNEOUS ROCKS.

The general relations of the rocks exposed in the vicinity of Golden suggests that the sedimentary rocks are younger than the intrusive and were deposited upon them. More detailed examination, however, suggests that the granite is intrusive. No dikes clearly connected with the main granite mass were seen in the sedimentary rocks, but many masses of the sedimentary rocks within the granite can be most readily accounted for by supposing that they were included at the time of intrusion. Pegmatite dikes are present both in the granite and in the sedimentary rocks. In the sedimentary rocks they are most abundant near the granite contact and decrease in abundance as the distance from the granite increases. These dikes are believed to be closely related to the granite and to represent a late phase of the igneous activity. If so, the granite is younger than the sedimentary rocks.

STRUCTURE.

The general structure of the range is that of an anticline or dome. The sedimentary rocks of the south side strike east and dip south, away from the mountains; and observations from the summit of the range indicate that on the north they dip north, also away from the mountains. This gives an anticlinal or dome structure to the range. In the vicinity of Golden streams have removed the sedimentary rocks and have exposed an intrusive granite mass. This relation strongly suggests that the main structural feature of the range is due to a doming of the sedimentary rocks by the intrusion of a granitic mass. This explanation is strengthened by the fact that the main structures due to folding and faulting in the general region trend north and south.

Many of the pegmatitic dikes in the sedimentary rocks are parallel to the bedding or schistosity, but some of them cut across the bedding.

ORE DEPOSITS.

The ore deposits occur in a series of veins that strike about N. 20° E. and dip 40°–50° SE., or even more steeply.

The Century vein, which is the most important yet developed, can be traced along the strike for several thousand feet. Whether it is continuous or is composed of a series of lenses along the same general strike has not been positively demonstrated. Several veins essentially parallel with the Century vein have been but slightly developed.

The mineral fissures cut the granite and what appear to be fragments of schist inclosed in the granite. At some points the fissure cuts through the schist with little change in size, but at other points it feathers out on entering the schist. The vein pinches and swells along both the strike and dip from a few inches to several feet in thickness.

The veins contain several distinct kinds of filling. At many points along the hanging wall the filling consists of a pegmatitic intergrowth of orthoclase and quartz, commonly designated "hanging-wall quartz." At other points it consists of coarse white quartz and at still other points of finer-grained quartz with sulphides and sulpharsenides or their oxidation products. The portions of the vein containing orthoclase and coarse white quartz carry little if any metal. The ore shoots are confined to the finer quartz.

The unoxidized ore contains galena, sphalerite, pyrite, chalcopyrite, and arsenopyrite, and the oxidized ore probably contains their common oxidation products. Rich oxidized ore carries visible free gold. Lead is commonly regarded as an indication of relatively rich ore, and at some points at least copper is considered to be less favorable.

The ore mined from the district has been largely oxidized, and reliable data as to the grade and character of the unoxidized material are not available. Small developments in the

Century mine are said to have encountered a good grade of unoxidized ore, and prospecting northeast of the Century has developed base ores that are said to be of good grade but not suited to treatment in the mills of the district.

Gold is the most valuable constituent of the ore, but silver and some lead have also been obtained.

The occurrence of the ore is similar to that of the Queen of Sheba mine in the Deep Creek Range (p. 485). The genesis of this type of deposit is discussed on page 486.

The mines that have made the principal production to the present time are the Century and the Susannah. These are on the same vein, the Century to the east and the Susannah to the west. Both are developed by tunnels. The outcrop of the vein is too low to permit deep development by tunnel, and if the vein is to be prospected at depth it must be by shaft or winze. This will necessitate the pumping of water. How much water would be developed by such work is of course unknown, but it is reasonable to suppose that it will be considerable.

There has been considerable prospecting by other companies in the vicinity of Golden and some prospecting in Pine Canyon, several miles to the east, on what is reported to be a large body of quartz in granite.

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PROMONTORY DISTRICT.

By B. S. Butler and V. C. Heikes.

INTRODUCTION.

The Promontory district was visited by the writers in August, 1915. Through the courtesy of Mr. S. S. Arentz, manager of the Lake View Mining Co., a much better idea of the geology was obtained than would have been otherwise possible in the time available. Free use has also been made of a published description [1] of the Lake View Mining Co.'s property by Mr. Arentz and of other data furnished by him.

[1] Salt Lake Min. Rev., vol. 17, pp. 12–15, 1915.

GENERAL FEATURES.

The Promontory district is in Box Elder County, near the south end of the Promontory Mountains, a north-south range extending southward from the north shore into the Great Salt Lake. The southern end of the promontory is crossed by the Southern Pacific Railroad (Lucin cut-off), which (through Saline station, on the western side of the promontory) serves the portion of the range in which ore deposits have been developed. The station, Promontory, is about 25 miles to the north, on the old line of the Southern Pacific.

The area in which ore has been produced is 3 to 4 miles north of the Lucin cut-off and about 1,000 to 1,500 feet above it. It is reached by a wagon road whose grade is moderate for most of the distance but becomes rather steep near the camp. Wagons and a motor truck haul ore to the railroad and supplies to the camp.

The range supports a rather scanty growth of cedar and other scrubby trees which are available as fuel. Some springs rise on the south end of the promontory but none near the camp. At the time of the writer's visit, water was brought in on the railroad for the section crew at Saline and for the Lake View Mining Co.'s camp, but the attempt to develop a supply in the vicinity was being considered.

The camp of the Lake View Mining Co., owners of the only producing claims of the district, is on an old beach of Lake Bonneville, predecessor of the present Great Salt Lake, which forms a bench on the mountain side and affords a level and very beautiful camp site.

The range lies within the area covered by the Fortieth Parallel Survey and was examined by Hague,[2] who says:

> This range extends from the northern limit of the map about 45 miles to the southward, forming a rocky promontory, which divides the two northern arms of Salt Lake, with a varying width from 4 to 7 miles, and reaching in its highest point 3,000 feet above the level of the lake. North of the railroad the range [North Promontory Range] is comparatively low, with rounded outlines, the greater part of its surface being covered with loose soil and grass, and showing but few outcrops. The underlying formation, however, belongs to the Wasatch limestone, and is evidently a continuation to the northward of the same beds which characterize the more important portions of the

[2] Hague, Arnold, and Emmons, S. F., Descriptive geology: U. S. Geol. Expl. 40th Par. Rept., vol. 2, p. 420, 1877.

range projecting into the lake. The railroad passes through a low depression in the range, which, on the summit, attains an altitude 4,943 feet above sea level, or over 700 feet above the level of Salt Lake. The old Pliocene Lake, at its highest elevation, unquestionably occupied this pass, isolating the main portion of the Promontory Mountains. * * * All along the east and west sides of the Promontory Mountains old terraces and beach lines may be traced with more or less distinctness, indicated by loose deposits of sand and gravel, or by benches cut in the hard mass of limestone. The elevation of the highest of these terraces is approximately 940 feet above the present level of the lake.

GEOLOGY.

SEDIMENTARY ROCKS.

No detailed description of the geology of the range has been published. Hague[1] says:

To the south and west of the railroad, at Promontory station, the range, which is quite narrow, consists of a series of limestones, of a prevailing gray color, in the lower part of which are dark heavy beds of nearly black limestone, all dipping to the westward at an angle of 38°. About 4 miles south of Promontory station the range widens rapidly to the westward, attaining a width of 6 to 7 miles, of which the western third is occupied by the same series of limestones, which here rise with an easterly dip and overlie a limited outcrop of Archean schists.

These Archean rocks are exposed on the southwest corner of this projection of the range and consist of quartzites and mica-bearing schists, closely resembling those described in the Archean bodies of the Wahsatch. The main crest to the east of this western projection is occupied by conformable strata, dipping, as already mentioned, about 38° W. They are much contorted, and show more or less faulting, so that their thickness can not be accurately determined. It is, however, not less than 3,800 feet. About the middle of the series there is an included zone of yellowish-brown sandstone, more or less calcareous, within which are several beds of gray limestone. Its lower portion is sharply defined from the underlying limestones, but 300 feet above, where it passes again into the limestones, it shades off gradually through shaly beds. The general strike of this portion of the range is N. 28° E.

Along the extreme eastern foothills, on the edge of the lower Quaternary plain, which borders the lake shore, are outcrops of easterly dipping beds, which evidently show a portion of the eastern half of an anticlinal fold, of which the main mass just spoken of is the western member. This anticlinal fold appears very distinctly in the group of hills about 8 miles south of Promontory station, of which Benada Peak is the culminating point. Here a distinct northern axis cuts the range, and south of that point the rocks dip to the eastward. Through the pass, about 1½ miles north of Benada Peak, passes a synclinal axis quite parallel to the anticlinal, which lies 1 or 1½ miles to the west of it. Here the easterly dipping members of the western anticlinal and the westerly dipping parts of the eastern or second anticlinal meet. The second anticlinal passes through Benada Peak itself and, as has been said, to the south of that point, for about 12 miles down the range, the greater part of the limestones dip uniformly to the east at angles varying from 20° to 40°. At Flat Rock Point, on the west side of the range, are found portions of the western members of this anticlinal fold, dipping at a gentle angle into the lake, and consisting, for the most part, of gray and drab limestones, among which are intercalated bands of yellowish-brown sandstone, similar to that described in the westerly dipping mass south of Promontory station.

From the westerly dipping limestones, about 5 miles south of Promontory station, near Antelope Springs, were obtained the following fossils: *Productus prattenianus*, *Spirifer opimus*, *Athyris subtilita*, [and] *Streptorhynchus* (fragments); while the limestones farther south afforded *Zaphrentis stansburyi* [and] *Productus semireticulatus*. These fossils are all clearly of Carboniferous age, though of themselves not distinctly characteristic, either of the Upper or Lower Coal Measures limestones. The thickness of the series and its relation to the underlying Archean, however, as well as its general lithological character, all serve to ally it rather to the latter division.

About 14 miles south of Benada Peak the Carboniferous limestones are found to abut unconformably upon a series of Archean schists, which occupy the whole lower 7 or 8 miles of the range, with a strike N. 30° to 35° W, and a dip to the northeast. The Archean strata consist largely of siliceous schists and imperfectly bedded hornblendic and micaceous gneisses, together with thick beds of quartzite and more or less interspersed argillaceous schists. Just west of the southernmost extremity of the range, the Archean rocks come nearly down to the water's edge, presenting a cliff, some 50 feet in height, of dark argillaceous schist, which has apparently a dip of 25° W.

Hague's statement that Archean rocks form the southern end of the promontory was apparently based on an examination along the western base, for limestone makes up an important part of the central and eastern part of the range.

Only the rocks forming the central portion of the series exposed were examined by the writers. The basal formation of the range is Archean schists. This is overlain by a great series of quartzite whose thickness has not been determined but is several thousand feet at least. This series is believed to be equivalent to the Cambrian and Algonkian quartzites and shales, which in the Wasatch Range are variable in thickness but in Big Cottonwood Canyon exceed 10,000 feet. Overlying the quartzite is 700 to 800 feet of shales, impure limestones, and sandstones, with some beds of rather pure limestone toward the top. Overlying this series are several thousand feet of heavy bedded limestones which were not examined.

[1] Op. cit., p. 428.

Fossils collected from the shale series overlying the quartzite and from the shale above the "middle bed" were examined by Edwin Kirk, of the United States Geological Survey, who reports:

The fossils are not in a very satisfactory state of preservation but approximate determinations are possible. All the evidence points to their lower Middle Cambrian age.

Lot 1.—Shale above lower "big" quartzite 100 to 400 feet above quartzite, about one-fourth of a mile north of Lake View camp: *Ptychoparia* sp., *Bathyuriscus* sp.

Lot 2.—South of Lake View camp in shale above ore limestone: *Micromitra* (*Iphidella*) *pannula* (White).

Lot 3.—In shale above (?) ore bedding, collected by S. S. Arentz: *Zacanthoides* sp.

Lot 4.—Float from shale above quartzite: *Neolenus* cf. *superbus* Walcott, *Bathyuriscus* cf. *B. productus* Hall and Whitfield.

Lot 5.—Shale above "ore limestone" south of Lake View camp: *Ptychoparia* sp., algae.

Lithologically and paleontologically the shales and limestones between the quartzite and the upper limestone series rather closely resemble the shales and limestones at a similar horizon in the Wasatch, Oquirrh, Tintic, and other ranges, though both the shales and limestones in the Promontory Range show a greater development than those in the ranges named. The limestone is, however, even more strongly developed at this horizon in northeastern Utah. The upper part of the quartzite series is doubtless of Cambrian age, and the lower part may be Algonkian, though this has not been determined. The limestone-shale series overlying the quartzite is determined by the paleontologic evidence to be Cambrian, and that of the upper limestone probably ranges from Cambrian to Carboniferous.

IGNEOUS ROCKS.

No igneous rocks were observed in the vicinity of the mineralized area. Mr. Arentz states that a dike 4 feet in width and traceable for about 150 feet cuts the heavy-bedded limestones east of the Lake View property. In the hand specimen this is a dark-green rock apparently having the composition of a rather basic diorite, or possibly diabase. Similar rocks are said to cut the quartzite west of the Lake View property.

STRUCTURE.

The general structure of the range at the southern end is monoclinal. The beds strike about N. 40° W. and dip 30°–40° NE. This apparent monocline may be the eastern limb of an anticline whose western portion has been removed by erosion, as indicated by Hague's description of the range farther to the north and by a small outcrop of west-dipping sediments near the south end of the promontory. Minor faulting trending north and also east has an observed displacement of only a few feet. A strong east-west break, 6 to 7 miles north of the south end of the range, along which the rocks to the south have been relatively depressed, was observed at a distance, and no details concerning it are known. Fissures striking about north and dipping steeply west are rather abundant throughout the area that has been prospected.

ORE DEPOSITS.

Before 1916 prospecting had been largely confined to two localities, both of which are near the southern and western side of the promontory. The activity is largely confined to the zinc-lead deposits.

ZINC-LEAD DEPOSITS.

Mr. Arentz,[1] manager, reports to the Lake View Mining Co. on the zinc-lead deposits as follows:

For several years previous to 1915 a coterie of Ogden men, headed by Mr. James Worthorspoon, Lorenzo Farr, John Farr, and Mr. Carlson, held two groups of placer claims covering a bed of marbleized limestone, and also a large portion of what is now the Lakeview Mining Co.'s property. This placer property was held by location over a period of some five years; the amount of work done was almost negligible. December, 1914, several men, headed by I. F. Farr, were employed to work on this placer property on the marble outcrop, about 1 mile north of the Judge Henderson wheat field. During noons and Sundays the workmen walked up the wash to the limestone beds outcropping above. Boulders of lead-zinc carbonate were discovered in the talus and traced to the outcrop of ore in place found at the top of the 100-foot bed of limestone forming the so-called middle bed in contact with shale. Four locations were then made. * * * After an examination made in February of this year [1915] by Samuel S. Arentz, of Salt Lake, a fifth interest was negotiated for and obtained on March 9. Mr. Arentz began operations as one-fifth owner, and under contract to manage the mine for one year.

The Lakeview Mining Co. was then incorporated for 500,000 shares, par value 5 cents. * * *

Your company has sold no stock; began operations without money in the treasury, all expenditures made by the original owners has been returned to them, and from the 1st of May, less than 60 days after beginning of operations, it has been self-supporting.

[1] Salt Lake Min. Rev., vol. 17, p. 12, 1915.

The net weight of ore shipped to August 1, 1915, was 1,961,900 pounds averaging—

Lead	7.7
Iron	1.1
Silver	.02
Gold	Trace.
Zinc	32.75
Sulphur	.2
Moisture	1.9
Insoluble	16.0

Gross returns for 21 cars, $35,636.75. The company reports the paying of dividends to August 1 of $8,119.75 and net balance of $7,180.14.

Prospecting of zinc and lead deposits at the time of visit had been confined almost entirely to the "middle" limestone bed, which is 50 to 75 feet in thickness and lies between members composed prevailingly of shale. The ores replace this limestone where it is in close association with north-south fissures. The largest deposits thus far developed are just beneath the overlying shale, but important mineralization occurs at lower horizons in the ore-bearing limestone. The ores are entirely oxidized, consisting of zinc and lead carbonate, a little hydrous iron oxide, and manganese oxide. The gangue consists mainly of unreplaced limestone with some quartz.

Observations were confined to very shallow developments and it is not possible to generalize as to the relations of the ores. The carbonate ores, however, were undoubtedly derived from the alteration of sulphides, though no sulphide was observed.

In the oxidation of mixed lead-zinc sulphides in limestone the lead ores generally remain essentially in the position of the original sulphides, and the zinc ores form at lower levels,[1] the zinc sulphate produced by the oxidation of the sulphides having passed into the underlying limestone and reacted with it to form zinc carbonate. In the Promontory district, however, zinc seems to be far more abundant than lead, and it is possible that this was the case in the sulphide bodies. In some places the zinc ores lie beneath the lead ores, as they do in other districts, but in other places this relation does not appear to obtain. Mr. Arentz[2] has pointed out, for instance, that in passing from the crest of the spurs toward the canyon bottoms the zinc shows progressive decrease and the lead corresponding increase. Determination of the general relations must therefore await further developments.

Prospecting has been carried on along the outcrop of the "middle bed" for about 4,500 feet. Numerous openings show bodies of ore, from which considerable ore has been extracted.

[1] Butler, O. M., Some recent developments at Leadville: the oxidized zinc crest: Econ. Geology, vol. 8, p. 1, 1913. Knopf, Adolph, Mineral resources of the Inyo and White mountains, Cal.: U. S. Geol. Survey Bull. 540, p. 81, 1914. Loughlin, G. F., The oxidized zinc ores of the Tintic district, Utah: Econ. Geology, vol. 9, pp. 1-19, 1914.

[2] Salt Lake Min. Rev., vol. 17, p. 13, 1915.

COPPER DEPOSITS.[3]

Copper deposits in the quartzite series on the western side of the promontory about 1½ miles northwest of Saline have been prospected for several years. In 1907 14 tons of hand-sorted ore averaging 3.85 per cent copper and 1 ounce of silver per ton were shipped.

The deposits outcrop on the crest of a ridge near the shore of the lake. The beds strike N. 45°–50° E. and dip 16°–20° SE. The primary deposits consisted of disseminated chalcopyrite and possibly bornite, which, at the surface, have been altered to carbonates.

The development consists of two shafts about 200 yards apart, sunk from the crest of the ridge to depths of about 50 and 120 feet. At a lower horizon an incline shaft has been sunk on a westerly pitch nearly at right angles to the dip of the beds to a depth of 80 feet, and from the vicinity of the same point a tunnel has been driven eastward for about 100 feet. From a point about 200 feet lower, near the shore of Great Salt Lake, another tunnel has been driven eastward for 452 feet to intersect the downward extension of the ledge outcropping on the ridge.

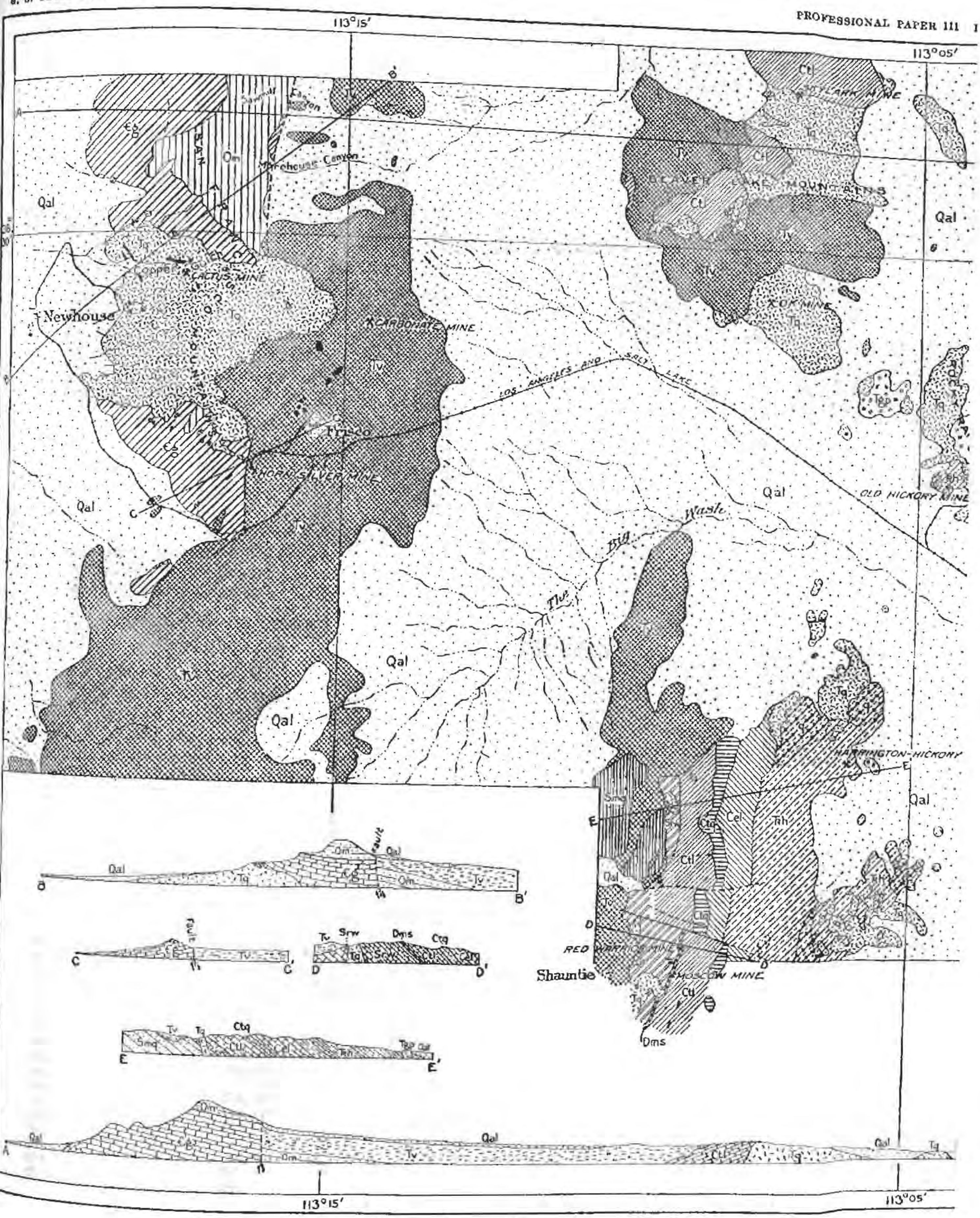
Some mineralized rock was observed in the prospect openings, and it is said that richer deposits were found at points not accessible at the time of visit. The ore shipped was obtained from surface blocks of mineralized quartzite 15 feet to 50 feet in thickness.

FREMONT ISLAND DISTRICT.

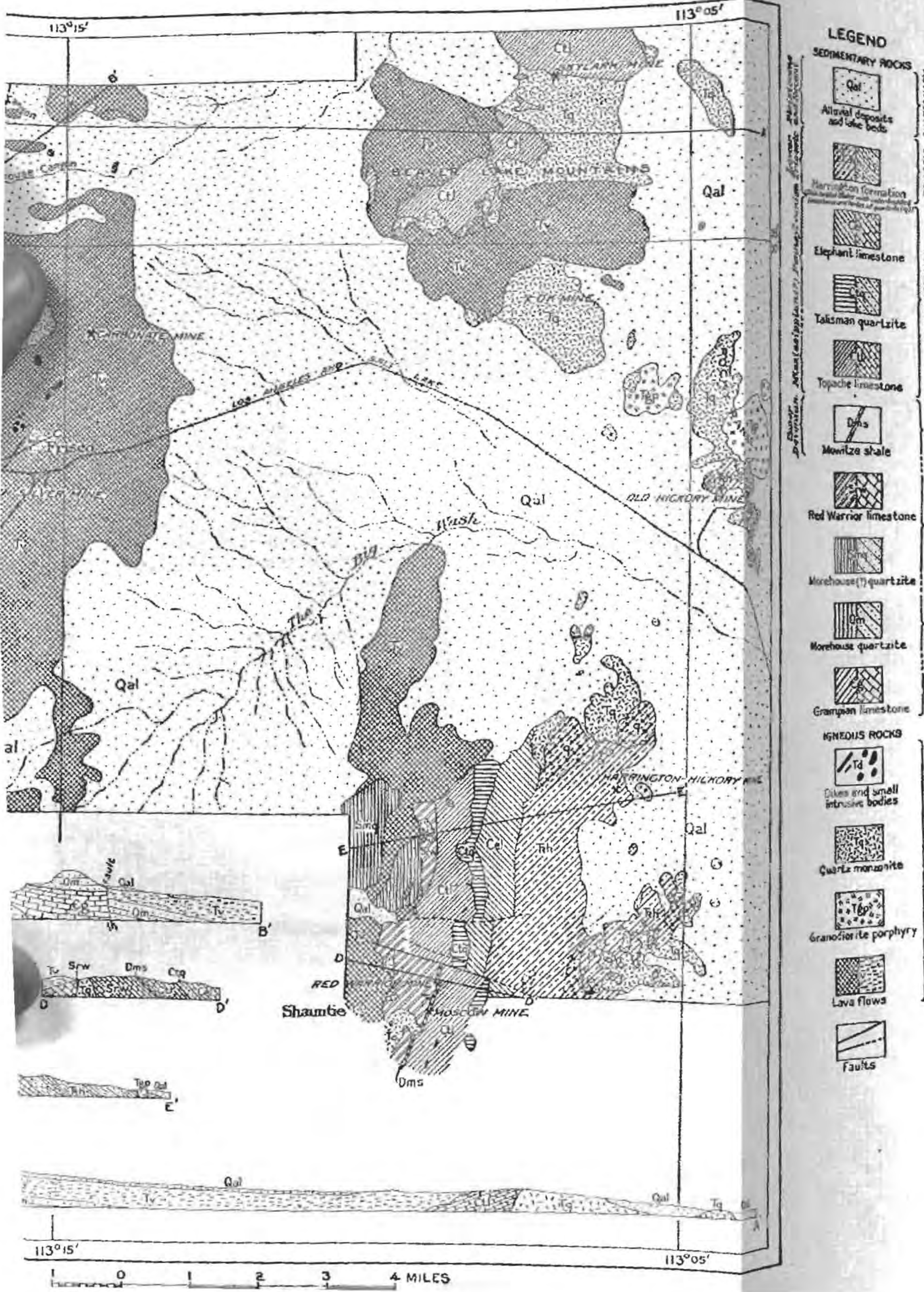
By V. C. Heikes.

The Fremont Island district, organized August 3, 1871, is in Weber County and includes the whole of Fremont Island in Great Salt Lake. Small veins carrying gold, silver, copper, and lead occur and were first developed by the Utah

[3] Based on observations by Mr. V. C. Heikes and information furnished by Mr. C. A. Redfield, of Ogden, Utah.



GEOLOGIC MAP AND SECTIONS OF THE MINING DISTRICTS OF THE SAN FRANCISCO REGION.



113°15'
113°05'
LEGEND
SEDIMENTARY ROCKS
Qal
Alluvial deposits and lake beds
QUATERNARY
Harrington formation
TRIASSIC
Elephant limestone
Talisman quartzite
Topache limestone
CARBONIFEROUS
Dms
Mowitza shale
DEVONIAN
Red Warrior limestone
SILURIAN(?)
Morehouse(?) quartzite
Om
Morehouse quartzite
ORDOVICIAN
Grampian limestone
CAMBRIAN (?)
IGNEOUS ROCKS
Td
Dikes and small intrusive bodies
Tq
Quartz monzonite
Tgp
Granodiorite porphyry
Lava flows
TERTIARY
Faults
BEAVER LAKE MOUNTAINS
SKYLARK MINE
CARBONATE MINE
Frisco
LOS ANGELES AND SALT LAKE
OLD HICKORY MINE
The Big Wash
HARRINGTON-HICKORY MINE
RED WARRIOR MINE
Shauntie
MOSCOW MINE
Qal
Tv
Tq
Ctl
Cel
Th
Srw
Dms
Ctq
Cg
B'
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D'
E
E'
1 0 1 2 3 4 MILES

& Nebraska Mining Co., 38 claims having been located by 1873, but none was ever patented. There is said to be on the island a great abundance of slate, some of which is suitable for roofing.

SAN FRANCISCO AND ADJACENT DISTRICTS.[1]

By B. S. Butler.

LOCATION.

The San Francisco, Preuss, Star, North Star, Beaver Lake, and Rocky districts, here discussed together because of their geologic relations, lie adjacent to each other in the north-central part of Beaver County, Utah, about 180 miles a little west of south of Salt Lake City. (See Pl. XL.) Milford, a few miles east of the district, on the Los Angeles & Salt Lake Railroad, is the railroad center of the region. A branch of the same railroad extends to Frisco and Newhouse and serves the Horn Silver, Cactus, and other mines.

The San Francisco and Preuss districts are in the San Francisco Range, the Beaver Lake and Rocky districts in the Beaver Lake and Rocky ranges, and the Star districts in the Star Range.

HISTORY AND PRODUCTION.

By V. C. Heikes.

The prosperous years of Beaver County began in 1872, when Shauntie, Shenandoah City, Elephant City, and South Camp were thriving. Most of the ore produced was treated at the Shauntie smelter, consisting of two small stacks erected in the summer of 1873 (closed 1877). In 1875 the Troy furnace (which ran for only a few months) was erected 5 miles south of Milford to treat Mammoth ores. The oldest producing mine, said by the Mormons to be the oldest mine in Utah, is the Rollins property in the Lincoln district; it was worked between 1860 and 1863 and made a few tons of lead in a primitive way. A 15-ton furnace was built in the fall of 1875 and was operated for two years.[2] Another authority[3] states that in the fifties (1854) a Mormon named Isaac Grundy erected the first furnace on the Pacific coast near the Rollins mine and melted the lead ore from this property, producing bullion which was hauled to Salt Lake and made into bullets. The Horn Silver mine, on a deposit which was discovered September 24, 1875, made steady shipments of ore until furnaces were erected in 1876, and from 1880 to 1884 was one of the largest producers of lead-silver ore in the State.

[1] Summarized from Butler, B. S., Geology and ore deposits of the San Francisco and adjacent districts, Utah: U. S. Geol. Survey Prof. Paper 80, 1913, from which descriptions of the mines or fuller details of the geology may be obtained.

SAN FRANCISCO DISTRICT.

The San Francisco district is about 7 miles square and lies upon both flanks of the San Francisco Mountains. It was organized August 12, 1871, and was of little importance until 1876, a year after the discovery of the Horn Silver mine. Frisco is the town and post office. (See Pl. XLI, *A*.)

The early history of the mines has been reviewed by Butler, who prepared the output figures in the subjoined table from the records of the United States Geological Survey.

[2] Tenth Census U. S., vol. 13, pp. 472-475, 1885.

[3] Eissler, M., The metallurgy of argentiferous lead, preface, 1891.

Meta s produced in the San Francisco and Preuss districts, Utah, to the close of 1917.

Year.	Ore (tons).	Gold (fine ounces).	Silver (fine ounces).	Copper (pounds).	Lead (pounds).	Recoverable zinc (pounds).	Total value.
1870-1901	....	3,545.00	13,718,280	4,327,047	230,040,964	....	$20,142,479
1902	18,250	202.73	112,813	717,353	3,657,063	....	293,690
1903	17,347	807.86	96,027	432,409	5,505,694	....	347,988
1904	15,912	545.04	110,541	1,588,287	7,432,855	391,676	417,902
1905	141,519	1,616.00	137,412	3,427,918	3,464,007	1,358,000	894,088
1906	236,229	2,667.67	289,165	5,108,127	4,762,488	780,276	1,553,814
1907	215,204	2,354,75	279,379	4,626,736	3,811,321	933,136	1,415,469
1908	220,005	2,032.19	106,877	5,609,611	1,900,371	....	918,939
1909	53,385	647.26	205,974	1,114,085	3,528,134	656,457	452,476
1910	77,781	596.75	249,156	984,310	3,908,122	451,879	468,245
1911	254,625	1,853.66	136,585	3,646,016	2,472,647	64,927	681,430
1912	189,446	1,450.89	183,780	2,216,191	4,735,712	1,173,366	802,758
1913	140,458	926.85	167,227	2,044,156	6,561,691	5,497,062	1,033,559
1914	86,810	579.23	153,812	1,435,845	5,494,252	7,143,746	866,607
1915	46,076	453.96	171,049	221,798	6,134,931	2,824,183	773,462
1916	241,090	1,264.72	303,867	1,726,515	4,104,648	3,450,671	1,396,422
1917	266,349	277.52	217,110	2,141,315	3,564,395	3,538,898	1,458,486
	2,220,486	21,822.08	16,639,054	41,367,719	361,079,295	28,264,277	33,917,814

The Horn Silver mine (see Pl. XLI) was discovered in 1875 and for about 10 years was one of the most productive mines of the State. After 1885 its production greatly decreased, but it has been in almost continuous operation to the present time. To the close of 1913 it had yielded metals of a total value of $20,768,471 and had paid in dividends $6,892,000.

The Beaver Carbonate mine was discovered in the fall of 1878 and the following year was purchased by the Frisco Mining & Smelting Co. for $150,000. It was an active producer for nearly seven years but was closed about 1885 and remained idle till 1908, when considerable development work was done but little metal produced. Its total metal output is estimated at 2,593 tons of lead and 533,910 ounces of silver, with a total value of about $808,000.

Other mines in the district have made small production.

PREUSS DISTRICT.

The Preuss mining district, in Beaver County, is an old district that was reorganized September 4, 1880. In that year it contained 25 recorded claims. The Cactus mine[1] has been the principal producer, yielding low-grade copper ore for concentration. A 50-ton concentrator using jigs was erected in the bed of Copper Gulch in the spring of 1883. In 1889 the Comet copper smelter was operated for about 30 days. In October, 1896, the Cactus Co. started the construction of a 200-ton concentrator. In 1900 the property was acquired by the Newhouse Mines & Smelters Co., later reorganized as the South Utah Mines & Smelters, which constructed a concentration mill and later on enlarged its capacity to 800 tons daily capacity. Production began in March, 1905, and to the close of 1913 the mine had yielded 24,155,073 pounds of copper, 9,535.37 ounces of gold, and 216,943 ounces of silver. The production by years of this property has been included in the output of the San Francisco district.

[1] Described in U. S. Geol. Survey Bull. 260, pp. 243-248, 1905; also Prof. Paper 80, pp. 174-178, 1913.

STAR DISTRICT.

The Star district is 5 to 10 miles southwest of Milford, a station on the Los Angeles & Salt Lake Railroad. Its organization and early history are fully reviewed by Huntley[2] as follows:

> The original Star district, 12 miles square, situated on the Picacho Range, a few miles southwest of Milford, was organized July 8, 1870. On November 11, 1871, the northern portion was reorganized as North Star district, and the two districts, called respectively North Star and South Star. * * * In the South Star the books showed 1,046 and in the North Star 581 locations, but probably not over 350 were owned in 1880. * * * The prosperous days of the district were in 1872, 1873, 1874, and 1875. Then there were the thriving mining camps of Shauntie, Shenandoah City, Elephant City, and South Camp. * * * Most of the ore produced was treated at the Shauntie smelter. Two small stacks were built at the town of Shauntie in the summer of 1873. In the following spring these were torn down, and one stack of 20 tons' capacity was built. This was burned in June, 1875, was rebuilt in the following autumn, and was shut down in the summer of 1877. * * * About 12,000 tons of ore were worked, which produced about 3,000 tons of bullion, containing $325,000 in silver and $10,000 in gold.
>
> The Troy furnace, erected in 1875 on the Beaver River bottoms, 5 miles south of Milford, to smelt Mammoth mine ore, ran but a few months.
>
> The Latey & Williams smelter is a single-stack custom smelter, and was erected at Milford, east of the districts, in the autumn of 1876.
>
> The Milford 10-stamp mill, built in the town of Milford, was erected in the fall of 1873, at a cost of $45,000, by * * * the Harrington & Hickory Consolidated Mining Co., to work the ores of the old Hickory mine, which had been sold to it for about $100,000. The mill ran a few months on about 35-ounce ore in the winter of 1873-74, and produced from $9,000 to $12,000 in base bullion.

An estimate of the early production, made by Butler,[3] covers the period 1870–1912. Since 1880 there has been very little activity in the Star district and the metal output was not important. The statistics of the production for 1904 to 1913, inclusive, are taken from the records of the United States Geological Survey.

[2] Op. cit., p. 118.

[3] Precious metals: Tenth Census U. S., vol. 13, pp. 471-474, 1885.

A. HORN SILVER MINE AND VILLAGE OF FRISCO; CONTACT OF QUARTZ MONZONITE AND LIMESTONE IN LOW SADDLE; SQUAW SPRINGS PASS AT LEFT.

B. VIEW [illegible] SHOWING OUTCROP OF CACTUS ORE BODY

Metals produced in the Star district (Star and North Star), 1870–1917.

Year.	Ore (short tons).	Gold (fine ounces).	Silver (fine ounces).	Copper (pounds).	Lead (pounds).	Recoverable zinc (pounds).	Total value.
1870-1902	....	750.00	500,000	....	11,000,000	....	$1,100,000
1904	1,100	36.28	10,310	62,500	93,000	2,391	17,580
1905	1,714	247.00	43,500	128,000	738,149	....	86,088
1906	1,985	60.50	34,603	67,994	556,300	....	69,267
1907	4,265	73.05	49,179	176,896	597,282	106,008	107,258
1908	2,835	71.40	41,550	94,276	1,144,329	54,902	86,583
1909	4,343	39.23	67,098	129,449	2,198,484	....	147,065
1910	4,660	53.84	88,628	141,533	2,309,102	61,854	171,491
1911	4,734	68.79	51,809	86,299	2,051,357	....	131,979
1912	5,144	63.60	51,355	67,875	2,916,957	2,820	175,554
1913	8,728	34.81	153,774	124,457	3,875,524	25,262	284,828
1914	7,096	284.79	131,426	58,286	3,840,954	....	236,115
1915	4,693	33.73	103,542	21,374	2,452,716	165,628	192,749
1916	7,823	123.84	49,188	153,696	1,717,284	467,734	253,903
1917	10,689	710.51	14,688	175,170	1,703,957	588,106	323,380
	69,809	2,651.37	1,390,650	1,487,805	37,186,395	1,474,705	3,383,840

NORTH STAR DISTRICT.

The North Star district, in Beaver County, organized November 11, 1871, is reviewed with the Star district and its production is included in the table of Beaver County.

BEAVER LAKE DISTRICT.

The Beaver Lake district is 12 miles west of Smyths siding on the Los Angeles & Salt Lake Railroad. The early operations in the district are recorded by Huntley,[1] as follows:

The Beaver Lake district is situated north of the Star and Rocky districts and was organized in August, 1871, upon the discovery of a belt of copper veins from an inch to 2 feet in width. Some work was done in 1872 and 1873, and a few tons of ore were shipped, assaying 30 per cent copper, 16 ounces silver, and $12 gold. * * * In September, 1872, lead and silver ores were discovered. The leading mine is the San Francisco, which was sold for $10,000. About $8,000 worth of high-grade silver-lead ore has been extracted from a 110-foot shaft. It has been idle since 1873. The Dexter and Mountain King are iron mines and shipped 400 tons of flux each between 1873 and 1877. A small vein containing graphite (or molybdenite) was also discovered. * * * The Riverside smelter was erected in 1873 at a point 7 miles north of Milford to work the copper ores of this district.

The largest production from this district came from the O. K. mine about 1900–1901; and the mine was again operated in 1906, 1907, and 1913 to 1917, inclusive. The production is included in that of the Rocky district.

ROCKY MINING DISTRICT.

The Rocky mining district, in Beaver County, was organized March 27, 1872, and is 10 miles northwest of Milford, on the Los Angeles & Salt Lake Railroad. It is about 1½ by 3 miles in extent and includes within its boundaries a small isolated range north of the Star district and east of the San Francisco district. The principal output has been from the Old Hickory mine. The production of the district is combined with that of the Beaver Lake district in the following table:

Metals produced in the Beaver Lake and Rocky districts, 1870–1917.

Period.	Ore (short tons).	Gold (fine ounces).	Silver (fine ounces).	Copper (pounds).	Lead (pounds).	Total value.
1870-1902	....	225.00	13,250	931,000	80,000	$105,000
1902-1917	108,766	415.69	86,831	4,160,281	35,671	1,205,784
	....	640.69	100,081	5,091,281	115,671	1,310,784

TOTAL METAL PRODUCTION OF BEAVER COUNTY.

The total metal production of the mines in Beaver County, which includes not only the districts in the San Francisco, Beaver Lake, Rocky, and Star ranges, but also those in the Wah Wah range (p. 527) and the Mineral Range (p. 529), is shown in the following table:

[1] Tenth Census U. S., vol. 13, p. 474, 1885.

Quantity of ore sold or treated in Beaver County, Utah, 1860–1917, and total output of metals recovered.

Year.	Quantity (short tons).	Gold.		Silver.		Copper.		Lead.		Recoverable zinc.		Total value.[a]
		Fine ounces.	Value.	Fine ounces.	Value.	Pounds.	Value.	Pounds.	Value.	Pounds.	Value.	
1860–1875		765.00	$15,814	257,720	$327,528			3,700,000	$216,400			$559,742
1876		[b]340.00	7,028	[b]226,625	262,885			[b]5,176,000	315,736			585,649
1877		[b]285.00	5,891	[b]420,000	504,000			[b,c]6,528,000	359,040			868,931
1878		[b]405.00	8,372	[b]646,625	743,619			[b,c]7,000,000	252,000			1,003,991
1879		[b]425.00	8,786	[b,d]756,700	847,504			[b,c]7,910,134	324,315			1,180,605
1880		[b]550.00	11,370	[b,d]1,108,530	1,274,809			[b,c]10,109,548	505,477			1,791,656
1881		[b]425.00	8,785	[b,d]1,501,341	1,696,515			[b,c]12,570,864	603,401			2,308,701
1882	[b]49,500	[b]967.00	19,990	[b,d]1,857,586	2,117,648			[b,c]45,423,988	2,225,775			4,363,413
1883	[b]43,900	[b]580.00	11,990	[b,d]1,652,980	1,834,808	[b,c]10,000	$1,650	[b,c]30,197,000	1,298,471			3,146,919
1884	[b]43,980	[b]484.00	10,005	[b,d]1,625,300	1,804,083	[b,c]5,000	650	[b,c]24,800,650	917,624			2,732,362
1885		[b]125.00	2,584	[b,d]420,000	449,400	[b,c]10,000	1,080	[b,c]9,800,000	382,200			835,264
1886	[b]5,140	[f]300.00	6,202	[f]250,000	247,500	[b,c]27,000	2,997	[b,c]3,800,000	174,800			431,499
1887	[b]5,440	[f]300.00	6,202	[f]235,188	230,484	[b,c]65,000	8,970	[b,c]3,124,000	140,580			386,236
1888	[b]6,310	[f]125.00	2,584	[f]191,100	179,634	[b,c]75,000	12,600	[b,c]3,758,740	165,385			360,203
1889	[b]12,880	[f]310.00	6,408	[f]325,330	305,810	[b,c]850,000	114,750	[b,c]9,129,800	356,062			783,803
1890	[b]20,057	[f]250.00	5,168	[f]560,880	588,924	[b,c]274,290	42,789	[b,c]10,818,000	486,810			1,123,691
1891	[b]25,520	[f]110.00	2,274	[f]677,160	670,388	[b,c]863,993	110,591	[b,c]15,155,760	651,698			1,434,951
1892		[f]130.00	2,687	[b,d]736,256	640,543	[b,c]60,000	6,960	[b,c]18,893,760	755,750			1,405,940
1893		[f]170.00	3,514	[f]720,144	561,712	[b,c]50,000	5,400	[b,c]14,261,000	527,657			1,098,283
1894		[f]125.00	2,584	[b,d]421,822	265,755	[b,c]87,786	8,340	[b,c]10,255,800	338,441			615,120
1895		[f]712.00	14,718	[b,d]700,094	455,061	[b,c]10,000	1,070	[b,c]14,691,600	470,131			940,980
1896		[f]505.00	10,439	[f]330,510	224,747	[b,c]5,000	540	[b,c]9,115,000	273,450			509,176
1897		[f]827.00	17,096	[f]296,824	178,094	[b,c]8,194	885	[b,c]12,180,000	438,480			634,555
1898		[f]720.00	14,884	[f]309,986	182,892	[c,f]139,291	17,272	[c,f]8,153,030	309,815			524,863
1899		[f]1,084.00	22,408	[f]244,939	146,963	[c,f]918,292	157,028	[c,f]4,983,453	224,255			550,654
1900		[f]281.00	5,809	[b,d]146,932	91,098	[c,f]769,648	127,762	[c,f]3,916,510	172,326			396,995
1901		[f]1,003.00	20,734	[f]427,382	256,429	[c,f]932,296	155,693	[c,f]6,907,969	297,043			729,899
1902		[f]1,283.00	26,522	[f]221,867	117,590	[c,f]914,088	111,519	[c,f]5,022,768	205,938			461,564
1903		[f]835.00	17,261	[f]100,214	68,146	[c,f]465,369	63,756	[c,f]5,365,694	233,759			382,922
1904		[g]631.00	13,040	[g]120,984	79,849	[g,h]1,650,787	211,301	[g]7,538,300	324,147	332,924	$16,979	645,316
1905	143,233	[g]1,863.00	38,512	[g]180,912	109,271	[g]3,555,918	554,723	[g]4,203,156	197,548	[g]5,130,220	302,683	1,202,737
1906	244,777	[g]2,728.16	56,296	[g]323,807	216,951	[g]5,406,068	1,043,371	[g]5,324,508	303,497	[g]780,276	47,597	1,567,812
1907	234,092	[g]2,707.45	55,968	[g]351,147	231,757	[g]5,639,444	1,127,889	[g]4,458,996	236,327	[g]1,039,144	61,310	1,713,251
1908	223,021	[g]2,280.74	47,147	[g]150,193	79,602	[g]5,706,406	753,246	[g]3,089,141	129,744	[g]54,902	2,580	1,012,319
1909	57,867	[g]762.92	15,771	[g]273,977	142,468	[g]1,247,235	162,141	[g]5,766,356	247,953	[g]656,457	35,449	603,782
1910	83,748	[g]827.89	17,114	[g]339,881	183,536	[g]1,128,785	143,356	[g]6,235,535	274,363	[g]513,733	27,742	646,111
1911	259,695	[g]2,301.10	47,568	[g]201,259	106,667	[g]3,739,282	467,410	[g]4,534,678	204,060	[g]64,927	3,701	829,406
1912	209,568	[g]1,650.31	34,115	[g]256,064	157,479	[g]3,040,400	501,666	[g]7,652,669	344,370	[g]1,176,186	81,157	1,118,787
1913	168,158	[g]1,117.85	23,108	[g]344,437	208,040	[g]3,137,234	486,271	[g]10,454,583	460,002	[g]5,522,324	309,250	1,486,671
1914	94,521	[g]1,002.18	20,717	[g]288,821	159,718	[g]1,511,888	201,081	[g]9,337,928	364,179	[g]7,143,746	364,331	1,110,026
1915	53,814	[g]630.23	13,028	[g]279,694	141,805	[g]428,916	75,060	[g]8,589,416	403,703	[g]2,989,811	370,737	1,004,333

1916	276,141	[g]2,023.62	41,832	[g]381,862	251,265	[g]3,203,688	788,107	[g]5,948,220	410,427	[g]3,969,405	531,900	2,023,531
1917	308,038	[g]2,192.06	45,314	[g]297,833	245,415	[g]3,702,085	1,010,669	[g]5,321,400	457,640	[g]4,133,464	421,613	2,180,651
Total [i]	....	37,139.51	767,739	21,160,906	19,588,392	49,638,383	8,478,593	411,403,954	17,980,774	33,507,519	2,577,029	49,392,527

[a] Average commercial prices used for each metal to make total for each calendar year.
[b] Estimates by V. C. Heikes from a separation of the total output reported by the Director of the Mint are given in the annual reviews of the Salt Lake Tribune and of the U. S. Geol. Survey *Mineral Resources*, 1882–1897. Part of the records of some early producers were used in the estimates.
[c] Bulk of copper and lead produced from Horn Silver ores.
[d] Horn Silver mine yielded 1,865,230 ounces for the years 1879–1881; 1,552,981 ounces in 1882; 1,116,898 ounces in 1883; 1,560,000 ounces in 1884; 315,900 ounces in 1885; 636,256 ounces in 1892; 321,823 ounces in 1894; and 143,932 ounces in 1900.
[e] Cactus and Horn Silver estimated.
[f] Director of Mint reports.
[g] Mineral Resources U. S. Geological Survey, 1901–1913.
[h] Cactus mine starts production.
[i] These totals are for mine output and aggregate more than if smelters' and refiners' figures were used.

Metals produced in Beaver County, 1860–1917, by periods.

Period.	Gold.		Silver.		Copper.		Lead.		Recoverable zinc.		Total value.
	Fine ounces.	Value.	Fine ounces.	Value.	Pounds.	Value.	Pounds.	Value.	Pounds.	Value.	
1860–1880	2,770.00	$57,261	3,416,200	$3,960,345	....	....	40,423,682	$1,972,968	....	....	$5,990,574
1881–1890	3,866.00	79,918	8,619,705	9,454,806	1,316,290	$185,486	153,423,042	6,751,108	....	....	16,471,318
1891–1900	4,664.00	96,413	4,584,667	3,417,253	2,912,204	435,848	111,605,913	4,162,003	....	....	8,111,517
1901–1910	14,922.16	308,465	2,490,364	1,485,599	26,646,396	4,326,995	54,112,423	2,450,314	8,507,656	$494,340	9,065,713
1911–1917	10,917.35	225,682	2,049,970	1,270,389	18,763,493	3,530,264	51,838,894	2,644,381	24,999,863	2,082,689	9,753,405
	37,139.51	767,739	21,160,906	19,588,392	49,638,383	8,478,593	411,403,954	17,980,774	33,507,519	2,577,029	49,392,527

CHARACTER AND METAL CONTENT OF ORES.

DRY OR SILICEOUS ORES.

The dry or siliceous ores shipped to smelters from Beaver County comprise very siliceous gold and silver ores and oxidized iron-manganese ores of little or no value except for fluxing. Some small lots of very rich gold ores were shipped from the Newton district at intervals and the bulk of the oxidized iron ore was shipped from the Bradshaw and Lincoln districts. The producers contributing to the output of dry or siliceous ore during the decade were the Rob Roy, Nip and Tuck, Sheep Rock, Hub and Lady Bryan, Old Hickory, Kitty Clough, Cave, Black Warrior, and Park mines.

The average grade of the ores shipped was as follows:

Dry or siliceous ore, with average metallic content, produced in Beaver County and shipped to smelters, 1906-1917.

Year.	Quantity (short tons).	Gold (value per ton).	Silver (ounces per ton).	Copper (per cent).	Lead (per cent).	Average gross value per ton.
1906.....	[a] 6,391	....	....	1.67	....	$6.45
1907.....	15	$12.13	20.87	.87	....	29.33
1908.....	18	79.89	2.11	....	....	81.00
1909.....	17	53.88	4.88	....	1.03	57.29
1910.....	2,107	1.74	3.64	.45	.52	5.32
1911.....	1,806	3.95	13.51	.44	.53	12.69
1912.....	28	56.86	56.50	....	....	91.61
1913.....	403	.91	8.20	.53	.60	8.03
1914....	1,026	.29	12.83	.40	0.76	9.04
1915....	110	21.15	8.39	.015	.96	26.77
1916....	1	83.00	41.00	....	....	110.00
1917....	91	.27	12.14	1.16	.67	17.78

[a] Iron ore.

COPPER ORES AND CONCENTRATES.

The copper ores include those usually carrying over 2½ per cent of copper. Sulphide ores were shipped most frequently by the Cactus, O. K., and Imperial mines and oxidized ores by the St. Mary, Kathleen, Cave, Commonwealth, Old Harrington, Harrington Hickory, King of the Hill, Buckeye, Creole, Horn Silver, Blue John, Copper Mountain, Baby Jack, Copper Ranch, Old Hickory, Montreal, and Copper King.

The copper concentrates were largely from ores treated at the Cactus mill.

The average grade of the ores and concentrates shipped from 1905 to 1913 was as follows:

Copper ore and concentrates, with average metallic content, produced in Beaver County and shipped to smelters, 1905-1917.

Year.	Quantity (short tons).	Gold (value per ton).	Silver (ounces per ton).	Copper (per cent).	Lead (per cent).	Average gross value per ton.
Crude ore.						
1905.....	200	....	2.70	2.00	....	$7.88
1906.....	457	$2.89	5.69	8.01	....	37.66
1907.....	27,231	.66	1.97	5.35	0.08	23.45
1908.....	4,126	1.35	1.64	13.19	....	37.04
1909.....	205	.71	1.38	9.00	....	24.82
1910.....	54	1.85	10.05	12.72	....	39.57
1911.....	692	.96	3.39	11.14	.05	30.67
1912.....	15,232	.09	1.30	2.74	....	9.93
1913.....	18,184	.02	1.19	2.68	....	9.06
1914....	1,223	1.01	3.70	13.51	....	39.00
1915....	3,078	.08	1.58	3.49	....	13.12
1916....	27,901	.35	1.13	2.64	....	14.11
1917....	32,368	.11	.61	2.34	.015	13.43
Concentrates.						
1905.....	16,897	$1.57	1.96	10.12	....	$34.35
1906.....	20,359	2.13	2.09	12.33	....	51.15
1907.....	21,426	1.36	1.68	6.28	....	27.59
1908.....	21,882	1.49	1.34	10.27	....	29.30
1909.....	4,307	1.17	1.18	9.54	....	26.57
1910.....	4,922	1.52	1.29	8.99	....	25.04
1911.....	21,111	1.51	1.39	8.14	....	22.60
1912.....	11,521	1.23	1.29	8.54	....	30.22
1913.....	8,972	.84	1.48	10.62	....	34.65
1914....	5,417	.71	1.39	9.59	....	26.99
1915....	254	1.37	2.13	23.43	....	84.45
1916....	4,282	1.24	1.88	16.78	....	85.05
1917....	5,650	1.57	2.16	16.47	....	93.29

LEAD ORE AND CONCENTRATES.

In general, the crude lead ores and concentrates are those containing over 4½ per cent of lead. The most important shipper of crude ore in the county was the Horn Silver mine, which yielded an important output each year during the last decade. The Moscow and Cedar Talisman shipped regularly, but in smaller quantities and for seven years the Red Warrior was a good shipper. Other shipping properties were the Harrington-Hickory, Summit, Big Gentile, Beaver Carbonate, Rebel and Wild Bill, Cave Consolidated, Atlas, Hecla, Hoosier Boy, Lydia, Flora, Jennie Fraction, St. Mary, Big Four, White Rock, Hobson, O. K., Oak Leaf, Lincoln, Silver King, Washington, Harriet, Majestic, Admiral Dewey, Hub, Monitor, Gold Reef, King David, Moscow Bonanza, Mammoth, Silver Glance, Utah Gold & Copper,

Oneida, Lower Cave, Indian Queen, and Volunteer.

The lead concentrates were chiefly from the Horn Silver and Beaver Carbonate dumps at Frisco but included a test lot of Moscow ore from the Star district.

The average grade of the ores and concentrates was as follows:

Lead ore and concentrates, with average metallic contents, produced in Beaver County and shipped to smelters, 1903–1917.

Crude ore.

Year.	Quantity (short tons).	Gold (value per ton).	Silver (ounces per ton).	Copper (per cent).	Lead (per cent.)	Average gross value per ton.
1903....	5,409	$2.01	11.27	0.71	34.63	$39.15
1904....	9,938	.90	10.46	1.90	29.30	37.65
1905....	6,647	.74	13.10	.05	26.20	33.52
1906....	14,551	.75	17.27	....	17.76	32.74
1907....	13,321	.62	17.12	.14	16.56	30.01
1908....	5,730	1.10	15.57	.35	22.43	29.13
1909....	11,905	.71	17.08	.41	18.71	26.76
1910....	12,684	.40	19.21	.45	17.11	26.97
1911....	9,458	.65	14.05	.63	22.48	29.92
1912....	13,488	.75	11.11	.49	21.48	28.53
1913....	16,050	.38	12.73	.42	18.45	25.61
1914....	10,525	.81	17.98	.49	27.42	33.45
1915....	6,646	.29	21.37	.34	31.08	41.54
1916....	15,598	.87	12.16	.52	11.78	27.73
1917....	18,716	1.44	9.35	.66	10.82	31.41

Lead ore and concentrates, with average metallic contents, produced in Beaver County and shipped to smelters, 1903–1917—Continued.

Concentrates.

Year.	Quantity (short tons).	Gold (Value per ton).	Silver (ounces per ton).	Copper (per cent).	Lead (per cent).	Average gross value per ton.
1903....	2,122	$2.68	15.00	....	34.98	$40.17
1904....	484	2.04	13.82	....	25.70	32.17
1909....	168	.14	33.47	....	24.69	38.78
1910....	37	.24	43.48	....	31.69	51.62
1911....	305	1.12	32.28	0.70	26.89	38.87
1912....	13	.15	22.69	2.40	6.14	27.61
1913....	2,341	.71	8.15	.12	24.27	27.37
1914....	3,943	.86	11.73	.28	27.46	29.52
1915....	3,800	1.50	21.08	.25	36.62	47.51
1916....	2,946	1.19	15.28	.45	18.05	38.37
1917....	1,285	1.29	9.34	.34	19.91	45.12

ZINC ORES AND CONCENTRATES.

The zinc ores and concentrates are those containing 25 per cent or more of zinc, irrespective of their precious metals. The bulk of the crude ore shipped was sulphides from the Horn Silver mine, but a trial shipment was from the Moscow. Siliceous and carbonate zinc ore was produced during several years from the Cedar Talisman property.

Concentrates of zinc were produced principally from the Horn Silver ores but include a test lot from the Moscow ores.

The average grade of the ores and concentrates was as follows:

Zinc ore and concentrates, with average metallic content, produced in Beaver County and shipped to smelters, 1904–1917.

Crude ore.

Year.	Quantity (short tons).	Gold (value per ton).	Silver (ounces per ton).	Copper (per cent).	Lead (per cent).	Recoverable zinc (per cent).	Average gross value per ton.
1904	522	....	3.16	....	....	31.89	$34.36
1905	8,445	$0.23	2.14	....	....	30.37	37.38
1906	1,615	....	10.00	....	....	24.15	36.27
1907	4,252	....	7.77	....	....	12.22	19.55
1908	99	.12	10.54	....	5.83	27.73	36.74
1910	859	.31	6.91	....	12.00	29.90	47.05
1912	2,031	....	1.15	....	5.22	28.89	45.27
1913	7,317	....	1.85	....	5.95	32.93	43.24
1914	2,402	....	....	....	....	33.77	34.44
1915	2,452	....	2.46	....	4.29	28.89	76.89
1916	497	....	3.00	....	3.52	21.08	63.35
1917	1,311	....	....	....	.43	25.58	52.93

Concentrates.

Year.	Quantity (short tons).	Gold (value per ton).	Silver (ounces per ton).	Copper (per cent).	Lead (per cent).	Recoverable zinc (per cent).	Average gross value per ton.
1912	3	$0.33	5.00	0.60	2.03	47.00	$72.00
1913	1,334	.03	.59	.03	.66	26.38	30.60
1914	2,069	....	....	....	....	38.25	39.01
1915	1,875	....	3.25	....	1.62	41.93	107.17
1916	535	....	....	....	....	38.91	104.29
1917	128	....	....	....	....	33.97	69.30

COPPER-LEAD ORES.

The copper-lead ores are classified like the copper and the lead ores. The producers of this kind of ore were the Moscow, Horn Silver, O. K., Lincoln, Progressive, Empire, Commonwealth, Wild Bill, and Kathleen.

The average grade of the ore shipped was as follows:

Copper-lead ore, with average metallic content, produced in Beaver County and shipped to smelters, 1903–1913 and 1917.

Year.	Quantity (short tons).	Gold (value per ton).	Silver (ounces per ton).	Copper (per cent).	Lead (per cent).	Average gross value per ton.
1903......	807	$0.82	4.00	22.00	17.00	$77.54
1904......	3,978	.78	2.18	15.93	18.42	58.79
1905......	1,200	4.13	35.00	5.00	30.00	69.28
1906......	719	.29	15.47	6.83	10.87	49.58
1908......	1,386	.07	16.41	3.02	17.71	31.62
1909......	2,593	.37	19.62	5.60	19.01	41.49
1910......	2,229	.20	28.19	2.15	36.23	52.79
1911......	74	.20	18.86	4.49	7.59	28.25
1912......	142	.24	16.16	11.06	17.20	62.16
1913......	7	.85	8.85	8.01	10.52	40.28
1917......	253	.08	13.55	3.07	14.09	52.26

LEAD-ZINC ORE.

The lead-zinc ore has come entirely from the Horn Silver mine. The average grade of the ores shipped was as follows:

Lead-zinc ore, with average metallic content, produced in Beaver County and shipped to smelters, 1909, 1911, 1914, and 1916.

Year.	Quantity (short tons).	Gold (value per ton).	Silver (ounces per ton).	Lead (per cent).	Recoverable zinc (per cent).	Average gross value per ton.
1909......	897	$0.18	9.05	12.92	36.59	$55.52
1911......	261	.27	10.01	11.62	12.44	30.21
1914......	6,083	....	2.52	8.04	32.37	34.44
1916......	628	....	....	8.68	27.13	84.70

PHYSIOGRAPHY.

By B. S. Butler.

Topographically and physiographically the San Francisco region is similar to other ranges of the Great Basin region. Characteristic features are north-south ranges rising abruptly from flat desert valleys. The ranges have several features in common. For example, in the Mineral Range on the east, the San Francisco Range within the area, and the Wah Wah Range next to the west, the following common characteristics are found. A gentle easterly slope and an abrupt westerly slope; a gentle easterly dip of the strata; a lava covering extending up the eastern slopes but absent from the western; and a rather straight western front that disregards the differing resistance of the component formations—features that are best explained by the supposition that the ranges were formed at a comparatively recent date by a breaking up of the area into blocks along north-south faults and the tilting of the resultant blocks, and that the areas between the ranges were subsequently partly filled by débris from the erosion of the higher portions.

The Beaver Lake, Rocky, and Star ranges do not show characteristics in common with the other ranges and may have resulted from other causes.

GEOLOGY.

The rocks of the area include sedimentary, intrusive, and extrusive formations, all of which are intimately connected with the ore deposits. (See Pl. XL, p. 502.)

SEDIMENTARY ROCKS.

The sedimentary rocks range in age from Ordovician and possibly from Cambrian to Triassic. (See fig. 52.) Although no marked structural unconformities have been recognized, there were probably periods of nondeposition and possibly of erosion while the sedimentary rocks were being formed.

The Grampian limestone, the lowest formation in the area, is exposed in the San Francisco Range. In large part it is a heavy-bedded blue dolomitic limestone, but it contains beds of light-gray limestone and siliceous and arenaceous beds, which are especially abundant in the upper 300 feet. Those near the top of the formation contain fossils of Ordovician age.

Overlying the Grampian limestone in the San Francisco Range is the Morehouse quartzite, which consists, at the base, of 400 to 500 feet of nearly white rather fine grained quartzite overlain by a pink quartzite nearly 1,500 feet thick, near whose base are some shaly members. A quartzite member about 2,500 feet thick that forms the base of the section exposed in the

Star district is believed to be the upper portion of the Morehouse quartzite the top of which is not present in the San Francisco Range. To what extent, if any, the two members are duplications has not been determined. No fossils were found in the quartzite, but as it lies between known Ordovician and Devonian rocks it has been provisionally assigned to the Ordovician and Silurian.

Next above the Morehouse quartzite is the Red Warrior limestone, which for the most part is a heavy-bedded blue dolomitic and in

Overlying the Mowitza shale is the Topache limestone of 1,500 feet of heavy-bedded blue limestone with beds of shale and chert.

Fossils collected near the center of the formation indicate that it is probably lower Carboniferous (Mississippian).

A persistent quartzite (Talisman quartzite) about 400 feet thick, though rather variable, separates the Topache limestone from the overlying Elephant limestone of Pennsylvanian age, a heavy-bedded dolomitic and siliceous limestone about 1,000 feet thick.

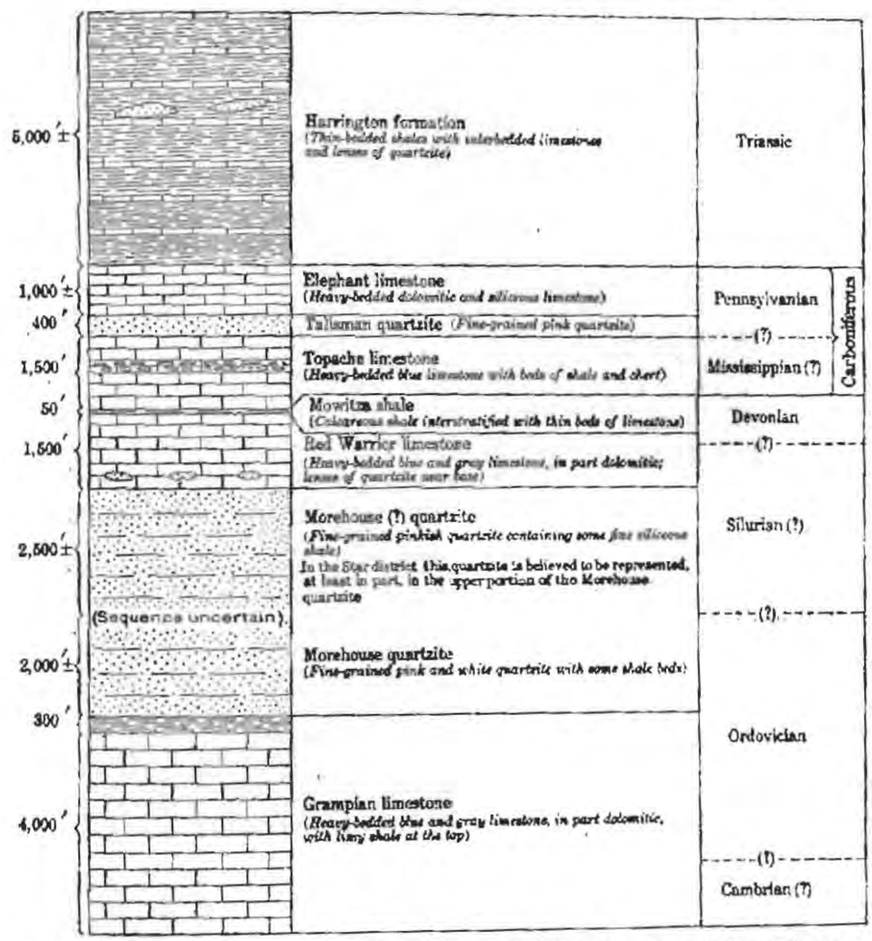


FIGURE 52.—Generalized section of the sedimentary series in the San Francisco and adjacent districts.

part rather siliceous limestone about 1,500 feet thick. In its lower part are lenses of quartzite and in its upper part beds of gray limestone. No fossils were collected from this formation, but as it is overlain by Upper Devonian rocks it is regarded as in part at least Devonian and possibly in part Silurian.

The next higher formation is the Mowitza shale, which consists of about 50 feet of calcareous shale interstratified with thin beds of limestone. Its age has been determined as Upper Devonian.

Overlying the Elephant limestone and representing the youngest consolidated bed in the area is the Harrington formation, which consists of shales with beds of limestone and lenses of quartzite. Approximately 5,000 feet of these beds are exposed. Fossils collected from the lower and central portions of the formation have been determined as of Triassic age.

Unconsolidated deposits in the district consist of lake beds and alluvial deposits of Pleistocene and Recent age.

IGNEOUS ROCKS.

INTERRELATIONS AND AGE.

The relation of the intrusive and extrusive rocks is far from clear at many points in the area. In the Rocky Range, however, dikes from the quartz monzonite stock intrude the lava flows, and in the San Francisco district, just northwest of Frisco, dikes of quartz monzonite porphyry similar in composition to the stocks cut the flow rocks. These facts, together with the porphyritic character of the quartz monzonite of the stocks near the contact with the extrusive rocks, especially well shown in the point extending into the lavas north of Frisco, indicate that the extrusive rocks are the earlier and that the intrusive rocks cut not only the sedimentary rocks but also the lavas.

The district furnishes no direct evidence of the age of the igneous rocks except that they are younger than the Triassic sediments. From a comparison with neighboring areas, however, it is believed that they are of Tertiary age.

EXTRUSIVE ROCKS.

Extrusive rocks are present over large areas in the region, and there is good evidence that they once covered the entire surface and were later in part removed by erosion. Their complete section is nowhere exposed, but their aggregate thickness amounts to several thousand feet. In physical character they range from tuffs to massive flows that resemble intrusive rocks; and in composition they range from rhyolite to olivine basalt. The two extremes in composition, however, are relatively scarce, and the great bulk of the extrusive rocks have the composition of quartz latite. (See p. 90.)

INTRUSIVE ROCKS.

Stocks are present in all the ranges in the area (see Pl. XL), and dikes and irregular bodies cut all the formations. The large bodies are of granitic texture and intermediate composition ranging from quartz monzonite to granodiorite. They are believed to have a common origin and to be simply variants resulting from the differentiation of a common magma. The chemical and mineral composition are given in another part of this paper. (See p. 96.)

The dike rocks are of at least two ages. Dikes of the quartz monzonite extend from the stocks into the adjacent rocks and more basic dikes cut the quartz monzonite stocks and other formations. Siliceous dikes are also present in the quartz monzonite and in the sedimentary rocks.

The more basic dikes vary in composition from those differing but little from the quartz monzonite to those in which the dark silicates compose a large part of the rock. The most basic rocks are of lamprophyric type.

The siliceous dikes range from irregular bodies of granitic rock (shown in Copper Gulch) that do not differ greatly in composition from some of the stocks to typical aplitic dikes composed essentially of quartz and orthoclase. Some of the aplitic dikes contain sulphide that is believed to be original. All the intrusive series are believed to have had a common origin, their different compositions being ascribed to differentiation of the magma.

STRUCTURE.

The main recognizable structural features of the region have resulted from a gentle folding followed by the intrusion of the monzonite stocks and the subsequent breaking of the region into blocks and the tilting of the blocks to form the present mountain ranges.

FOLDS.

On the west side of the San Francisco Range the lower beds of the Grampian limestone have been folded into a broad anticline that pitches gently north. The western limb of the upper beds, however, has been entirely removed, and in the Beaver Lake and Rocky ranges the earlier structural features have been entirely masked by those resulting from the intrusion of the quartz monzonite. In the Star district folds were not observed.

STRUCTURAL FEATURES RESULTING FROM INTRUSION OF IGNEOUS ROCKS.

The intrusive rocks for the most part broke through the earlier formations instead of spreading out in laccolithic form. They did, however, dome the overlying rocks to some extent, for these commonly dip away from the center of intrusion.

In the Star district, especially, an intrusive mass seems to have forced a block of sedimentary rocks bodily before it to make room for the entering material. To what extent "stop-

ing" (the engulfment, sinking, and dissolving of the invaded rock) provided space for the entering material is not definitely known, but the writer is inclined to the view that its effect was of minor importance, as Boutwell[1] believes it to have been in the Park City district.

FAULTS.

The most important structural features of the region are the result of faulting. Normal faulting is usually associated with the Basin Range structure and is believed to outline the San Francisco Range both on the east and west. A fault on the east, exposed in the workings of the Horn Silver mine, has a known displacement of 1,600 feet and doubtless much more. (See fig. 53.) Another notable normal fault passes northeast through Squaw Springs Gap in the San Francisco Range and throws the lavas on the south of the range down against the limestone on the north.

The intrusion of the quartz monzonite bodies is believed to have laterally displaced the surrounding rocks. Such a displacement is shown in the central portion of the Star district, and similar displacements are possibly present, though less clearly shown in association with other stocks. In the Star district there has been movement along planes that are essentially horizontal but that have irregularities resembling a warped surface. The rocks along the fault planes are highly polished and grooved, but it is not demonstrated that there has been extensive movement.

Faulting has probably been in progress over a long period. Some important faults doubtless formed before the intrusion of the quartz monzonite, and others have certainly occurred since. The faulting doubtless extended into late Tertiary time and may be still in progress.

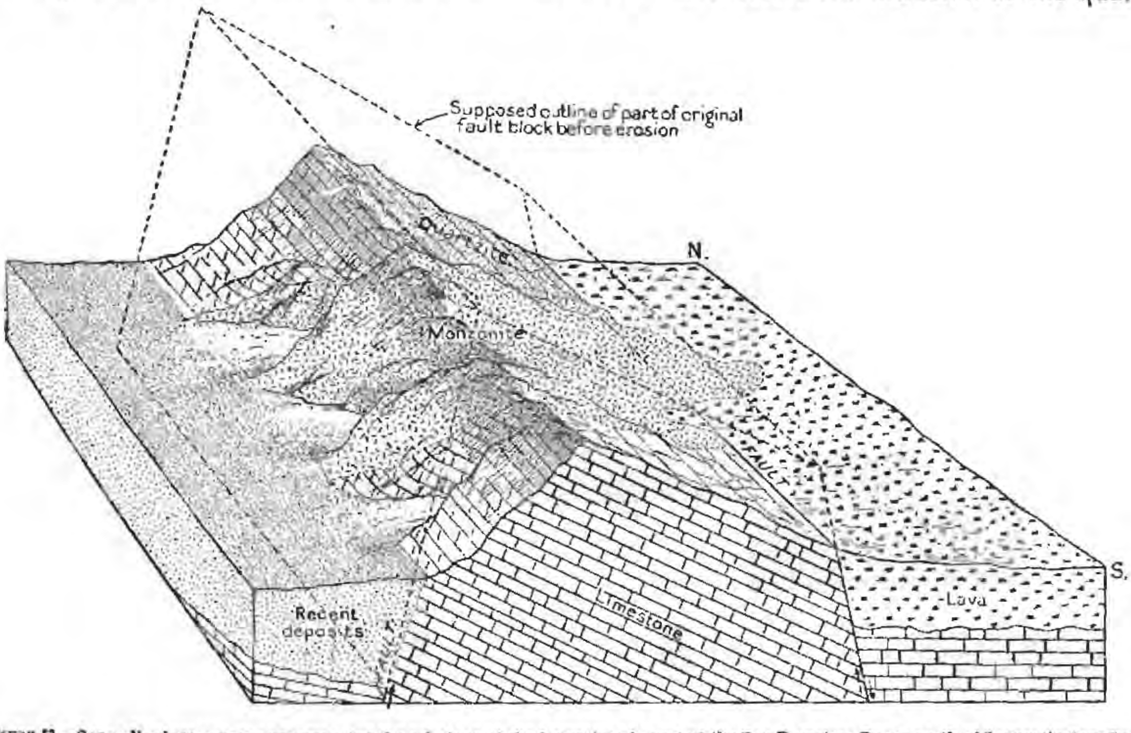


FIGURE 53.—Generalized stereogram representing the relations of the formations in part of the San Francisco Range north of Squaw Springs Pass.

FISSURES.

Fissures are important in the area, as they have furnished channels for the passage of the ore-bearing solutions. In the Star district most of the important fissures strike nearly east and dip vertically or very steeply. In the other districts the fissures show less uniformity of direction. Fissures in the sedimentary rocks were probably formed for the most part at the time of the quartz monzonite intrusion by stresses in the limestone resulting from the injection of the igneous material. Some little fissuring, especially near the contact, may be attributed to the stresses caused by the shrink-

[1] Boutwell, J. M., Stratigraphy and structure of the Park City mining district, Utah: Jour. Geology, vol. 15, p. 458, 1907

age of the cooling mass. Probably similar causes led to fissuring in quartz monzonite.

METASOMATISM.

ALTERATION OF QUARTZ MONZONITE.

In general the quartz monzonite has been little altered except along fissures and zones of fracture, where, in its most highly altered condition, it has been changed to essentially a quartz sericite rock with variable amounts of minor constituents. Such zones are especially well shown in Copper Gulch in the San Francisco Range and in the O. K. zone in the Beaver Lake Mountains, though they are present at many other localities.

In passing from unaltered rock to a highly altered zone the stages of the alteration can be seen. The dark silicates are usually first attacked and pass over to chlorite and carbonate and eventually largely to sericite; the feldspars become more and more sericitized till they are composed largely of that mineral; and finally even the quartz crystals are broken up and filled with sericite. In the two zones most carefully examined the most marked difference in the alteration is that rather abundant carbonate was formed in the Copper Gulch zone and none at all in the O. K. zone. The chemical composition of the fresh and altered rock in the two zones (pp. 164–165) shows that silica (SiO_2) has decreased somewhat in both. Alumina (Al_2O_3) shows little change; in the Cactus deposit it has slightly increased, in the O. K. deposit slightly decreased, the resulting differences, however, being no greater than might be found in two samples from the same rock mass. In the Cactus deposit the oxides of iron have remained nearly constant, but in the O. K. deposit iron has been removed. Magnesia (MgO) has been reduced in both zones, undoubtedly by the alteration. Both lime (CaO) and soda (Na_2O) have been almost completely removed, but potash (K_2O), especially in the Cactus zone, and combined water show marked increase. Titanium oxide (TiO_2) remains nearly constant. Carbon dioxide (CO_2) has been markedly added in the Cactus zone but not in the O. K. zone. Sulphur and copper have been added in both zones. The samples selected for analysis contained little sulphide and in this respect do not represent the average of the altered rock.

The chemical and mineralogic changes that have taken place in the rock give some indication of the composition of the solutions that produced them. Elements that have been added to the rock by these solutions were necessarily carried by them. Elements that were removed may have been already contained to some extent in the solutions, though probably not in large degree. From this it may be inferred that the solutions contained potassium, sulphur, and copper and in the Copper Gulch ore zone also iron and carbon dioxide. It is probable that the iron and carbon dioxide were present in the solutions that produced the alteration in other zones but not in sufficient quantity to be added to the rock. The fact that the solutions removed neither silica nor alumina might well indicate that they were not deficient in these substances.

ALTERATION OF LAVAS.

The lavas have suffered extensive alteration in several areas, especially along the base of the San Francisco Range near Frisco and in the central portions of the Beaver Lake Mountains and of the southwestern San Francisco Range.

The characteristic alteration of the lavas is a pronounced sericitization and silicification. In the early stages the dark silicates alter to chlorite and carbonate and in advanced stages magnesium, calcium, and sodium are largely removed. In extreme phases of alteration the resultant rock is composed essentially of quartz, andalusite, and sericite. Andalusite does not appear in the rock so long as feldspar is present. Apparently mica formed so long as the rock contained sufficient sodium or potassium to combine with the alumina set free by the breaking down of the feldspars, and only when the feldspar had entirely altered did further removal of the bases result in the formation of andalusite.

The following tables give a partial analyses of the lavas in different stages of alteration and the mineral composition calculated from the analyses:

Partial analyses and mineral composition of fresh and altered lava from San Francisco region, Utah.

Partial analyses.

	1	2	3	4
SiO_2	64.48	76.74	72.32	67.93
Al_2O_3	....		20.96	
Fe_2O_3	....	16.10	.50	19.46
FeO	....		....	
MgO	None.	.10	None.	.28
CaO	1.95	.34	.15	1.42
Na_2O	4.81	.58	.55	3.54
K_2O	3.39	3.99	.93	3.91
H_2O	....	2.34	3.91	......
TiO_2	....	....	1.10	......

Mineral composition.

	1	2	3	4
Quartz	20	58.0	56.34	31
Orthoclase molecule	20	....	....	22
Albite molecule	40	....	....	30
Anorthite molecule	10	....	....	7
Hornblende and biotite	....	....	....	3
Muscovite molecule	....	34.2	7.96	......
Paragonite molecule	....	6.7	7.64	......
Andalusite	....	....	26.35	......
Ilmenite	....	....	1.05	......
Rutile	....	....	.55	......
Calcite	....	.6	....	......
Lime (CaO)	....	....	.15	......

1. Quartz latite near summit of Beaver Lake Mountain north of O. K. mine (specimen 187). R. C. Wells, analyst.
2. Altered volcanic rock from ridge north of O. K. mine (specimen 189). George Steiger, analyst.
3. Highly altered volcanic rock from ridge west of O. K. mine (specimen 193). R. C. Wells, analyst.
4. Latite northeast of Frisco (specimen 20). George Steiger, analyst.

Mineralogically, alteration of the lava, especially in its earlier stages, shows many similarities to that of the quartz monzonite. Chemically, it far more closely resembles the results of weathering, where the change is the result of a progressive leaching of the different elements with no notable additions. The chief mineralogic difference is that the minerals are hydrated in the weathered rock but are anhydrous in the altered lavas.

ALTERATION OF SEDIMENTARY ROCKS.

Alteration of the sedimentary rocks adjacent to the quartz monzonite bodies, commonly designated contact alteration, differs greatly in different rocks and from point to point in the same rock. Commonly quartzite and shales show comparatively slight change and limestone more extensive alteration.

At many localities the limestone has been merely marmarized, but at others both its character and composition have been greatly changed. These differences are especially well shown around the stock in the San Francisco Range. Marmarization is the characteristic alteration on the north side of the stock and is important at some points along the south side, but at others on the south side contact silicates make up the bulk of the rock. The marmarization seems to have been the earliest effect of the intrusion, the recrystallization of the limestone being due largely to the heat of the intrusive material, and the silicate zones seem to have been produced slightly later, when the outer portion at least of the stock had solidified and the solutions from deep-seated sources were directed into certain parts of the limestone through fissures.

The character of the silicate zones was influenced to an important extent by the original composition of the limestone. Diopside and tremolite are abundant where the rock was notably magnesian, and garnet is more characteristic where it was more purely calcium carbonate. At some points, however—notably in the Rocky district, where iron ore has replaced limestone—the original material has been very largely removed.

In large part the minerals of the contact zone are contemporaneous, though in places the contact silicates are cut by veins composed of quartz, sulphides, magnetite, and even of feldspar. Distinctly later than the contact silicates are veins composed largely of magnesite ($MgCO_3$) and, near the iron deposits in the Rocky Range, veins of the rare mineral thaumasite ($3CaO.SiO_2.SO_3.CO_2.15H_2O$).

Away from the igneous contact silicates decrease and carbonates increase, though along fractures the silicates are present for a considerable distance and grade into veins where the alteration of the wall rock is chiefly silicification. The width of the silicate zone is very variable. South of the stock in the San Francisco Range it has a maximum width of fully one-fourth mile from an exposed contact, but at other points it is only a few yards.

The minerals forming the zone as already noted vary greatly from place to place. They include garnet (grossularite and andradite molecules are present in varying amounts), diopside, tremolite, vesuvianite, muscovite, epidote, chlorite, fluorite, quartz, calcite, specularite, magnetite, pyrite, and chalcopyrite.

Molybdenite, sphalerite, and galena are rather rare.

Analyses of specimens that represent changes that have taken place in the alteration are given on pages 170.

In comparing the analyses of the limestones to determine the changes that have taken place in alteration it is necessary to consider changes in the volume and the density of the rock. It has not been shown positively whether the volume has increased or decreased as a result of alteration, but it is believed that the change, if any, has been slight. The change in density, as shown by the specific gravity of the rocks, has been considerable. If the volume is assumed to have been constant, the amount of addition or subtraction of the several oxides can be determined by calculating the amount of each present in a given volume of rock. (See p. 170.) The changes, of course, differ at practically every point. Some of the more important, however, doubtless apply with varying intensity in all parts of the zone and represent the general change that has taken place. Generally speaking, silica shows a marked increase, the addition to each of the two highly altered rocks being almost identical. Alumina and ferric oxide also show a marked increase; the amount of each added to the different rocks differs, but the sum of the two is more nearly equal. Ferrous oxide is not important in either the unaltered or altered rock. Magnesia shows a decrease, but this can not be certainly ascribed to alterations, for the original magnesia content varies sharply within very short distances. Calcium shows a slight decrease in both of the altered rocks, and carbon dioxide is practically absent from both. Copper, zinc, and lead, and probably small amounts of other metallic elements have been added. Sulphur has been added, and in some parts of the zone potassium has been notably added, as indicated by the presence of muscovite. To sum up, it seems very certain that there have been important additions of silica, alumina, ferrous oxide, sulphur, copper, and zinc, and lesser additions of potassium, manganese, and other metals. It is logical to assume that these substances were contained in the solutions entering the limestone supposedly from a crystallizing magma.

COMPARISON OF ALTERATION OF DIFFERENT KINDS OF ROCK.

The solutions that effected the alteration in the quartz monzonite probably contained silica, potassium, iron, sulphur, copper, and carbon dioxide, and possibly alumina. The solutions that effected the alteration in the limestone contained silica, alumina, ferrous oxide, sulphur, copper, zinc, potassium, and other substances in minor amount. The similarity of the solutions seems in accord with the belief that they had a common origin and that they were given off by a crystallizing magma.

The altered volcanic rock in the areas of extensive metamorphism shows no important additions of substances but rather a progressive leaching. This would seem to indicate that the solutions differed from those affecting the quartz monzonite and adjacent sedimentary rocks and may have been ordinary atmospheric waters. Such waters, heated by the intrusion of the quartz monzonite magma, might be expected to produce an alteration chemically similar to but mineralogically different from weathering.

ORE DEPOSITS.

MINERALIZATION.

The ore deposits of the San Francisco region are believed to be of essentially the same age, the deposition of all the ores closely following the intrusion of the quartz monzonite. The marked differences in the deposits are probably due chiefly to the character of the rock in which the deposits were formed; to distance from the intrusive body, which affected the temperature and pressure; and to the time of formation, the solutions in the later part of the general period of mineralization probably being of somewhat different composition from those that were active at its beginning.

INFLUENCE OF ROCK TYPES.

The character of the rock in which the deposits were formed was doubtless one of the more important factors in determining the general type of the deposit.

DEPOSITS IN QUARTZ MONZONITE.

The quartz monzonite has been mineralized at numerous localities in the region, but so far mineralization has been shown to be extensive

at only two places—in the Cactus ore zone in Copper Gulch (see Pl. XLI, *B*) and in the O. K. ore zone in the Beaver Lake district. Characteristically the deposits carry copper and some gold and silver, though some veins carrying galena have been opened.

In both zones the deposits are associated with fractures along which there has been a

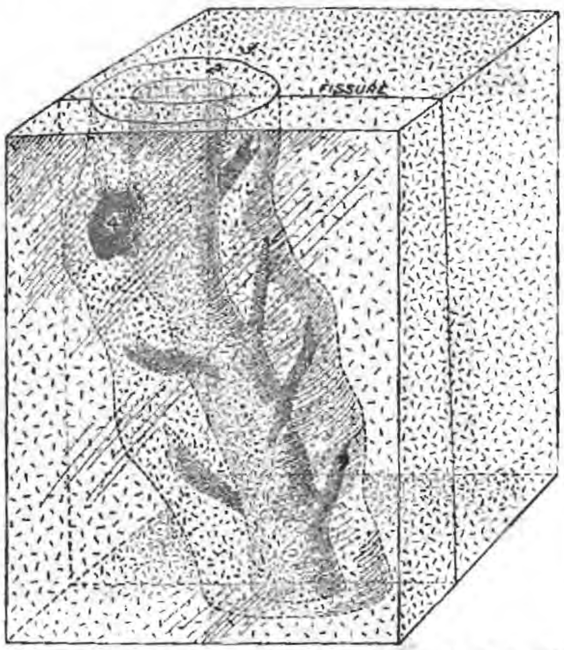


FIGURE 54.—Generalized stereogram showing the relation of pegmatitic quartz and altered and mineralized quartz monzonite in the O. K. mine. 1, Pipe of pegmatitic quartz; 2, altered quartz monzonite; 3, quartz monzonite; 4, high-grade ore.

brecciation of the rock but probably not extensive displacement. The deposits are more or less chimney shaped, especially the O. K. deposit, which consists of a central "chimney" of pegmatitic quartz surrounded by altered and mineralized quartz monzonite. (See fig. 54.) In the Cactus ore zone the ore and gangue minerals are deposited in spaces between corroded fragments of the quartz monzonite. In both zones the structural relations indicate that the spaces occupied by the ore and gangue minerals were formed largely by the solution of the rock in the early stages of mineralization and not by dynamic movement.

In the O. K. deposit the solutions were apparently relatively confined, and the dissolving action was strong, resulting in the formation of a more or less cylindrical channel with a maximum dimension of fully 100 feet, now filled with quartz, some of whose individual crystals have a diameter of 10 inches and a length of 2 feet. The body as a whole strikingly resembles a coarse pegmatite, though no feldspar or mica are present. Sulphides are abundant in the main chimney only locally, as in the ore body on the second level, where by enrichment they form high-grade ore. They are much more abundant in the small veins of quartz extending from the main mass into the adjacent rock. The characteristic primary minerals in the O. K. deposit are quartz, chalcopyrite, and pyrite with molybdenite in relatively small amount. An aplitic rock, probably a dike, exposed in the bottom of the shaft, contains chalcopyrite and molybdenite, apparently as original constituents.

The Cactus ore zone contains the minerals found in the O. K., and also hematite, magnetite (?), tourmaline, siderite, anhydrite, and barite in important amounts. The sequence of deposition is rather definite. The earliest effect of the ore solutions was the sericitization of the quartz monzonite and the deposition of quartz, chalcopyrite, and pyrite and small amounts of hematite and tourmaline in the wall rock. This was followed by the deposition of hematite and tourmaline and the continued deposition of quartz and the sulphides, mainly in open spaces. Still later deposition in the open spaces consisted mainly

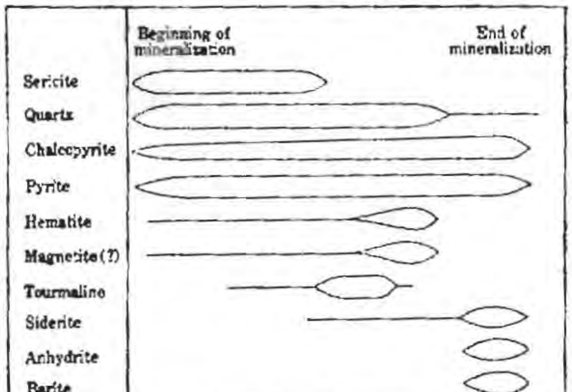


FIGURE 55.—Diagram showing the relative period of formation of the principal ore and gangue minerals of the Cactus ore zone.

of siderite, anhydrite, and barite, together with the sulphides. (See fig. 55.)

The earlier mineralization of the Cactus ore zone was similar to that of the O. K. ore zone, and the final differences may be due to the longer and more varied mineralization of the Cactus zone. The later minerals are in general those that form under conditions of less heat

and pressure, and the succession might naturally be attributed to a gradual reduction of the heat and pressure in the zone. Opposed to this hypothesis, however, is the presence of anhydrite, which, differently from most salts, decreases in solubility with increase in temperature and naturally would not precipitate from a cooling solution. Lindgren[1] says: "It is suggested as a possibility that during the later part of mineralization the anhydrite was precipitated by a reaction between ascending solutions of sodium sulphate and descending solutions containing calcium carbonate."

The formation of barite, anhydrite, and other sulphates as primary minerals in ore deposits is discussed on page 184. It is concluded that at comparatively low temperature they may form from igneous emanations.

DEPOSITS IN SEDIMENTARY ROCKS.

CONTACT DEPOSITS.

The typical contact deposits occur as very variable replacements of the limestone near the quartz monzonite in a zone differing greatly in thickness. In most places the replacement consists largely of lime and magnesian silicates with variable amounts of sulphides, but locally, as at the Old Hickory mine, it consists largely of magnetite.

The primary contact deposits are of low grade and, except in the magnetite zones, have been little mined, production coming mainly from the oxidized zone. (See p. 523.) Characteristically they carry copper, though other metals are present and iron may form an important commercial constituent.

REPLACEMENT-FISSURE DEPOSITS.

In most massive limestones replacement along fissures is rather uniform in the different beds, producing a tabular deposit parallel with the fissure. Where the sediments differ in physical character and in chemical composition, however, the ore deposition extends out from the fissure in particular beds for considerable distances but leaves adjacent beds largely unaffected. This selective replacement is probably due in part to physical and in part to chemical differences in the beds.

The tabular development is perhaps best shown in the Mammoth mine deposit in the massive Topache limestone, which, though it shows a pronounced swelling or extension in some beds, also replaces the intervening beds to a considerable extent.

Replacement along particular beds is well shown in the Harrington-Hickory mine and in the mines in the limestone underlying the Mowitza shale, especially the Red Warrior and Moscow mines, in which the replacement is almost exclusively along certain beds, the resultant deposits forming chimneys that follow the intersection of the ore fissure and the replaced bed. (See fig. 56.) In the de-

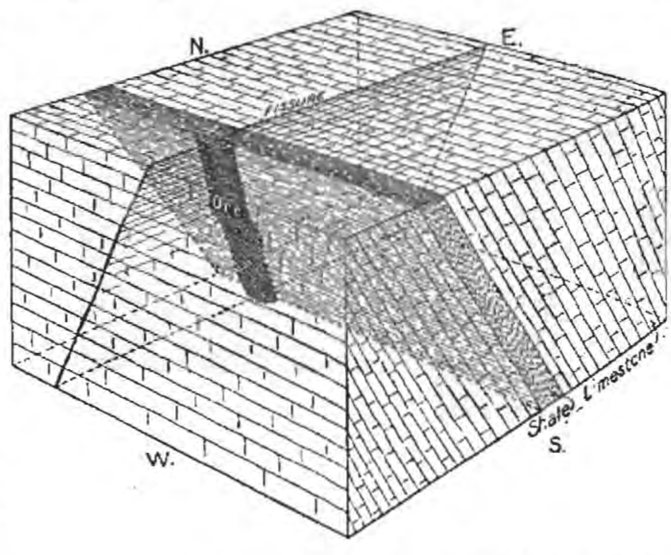
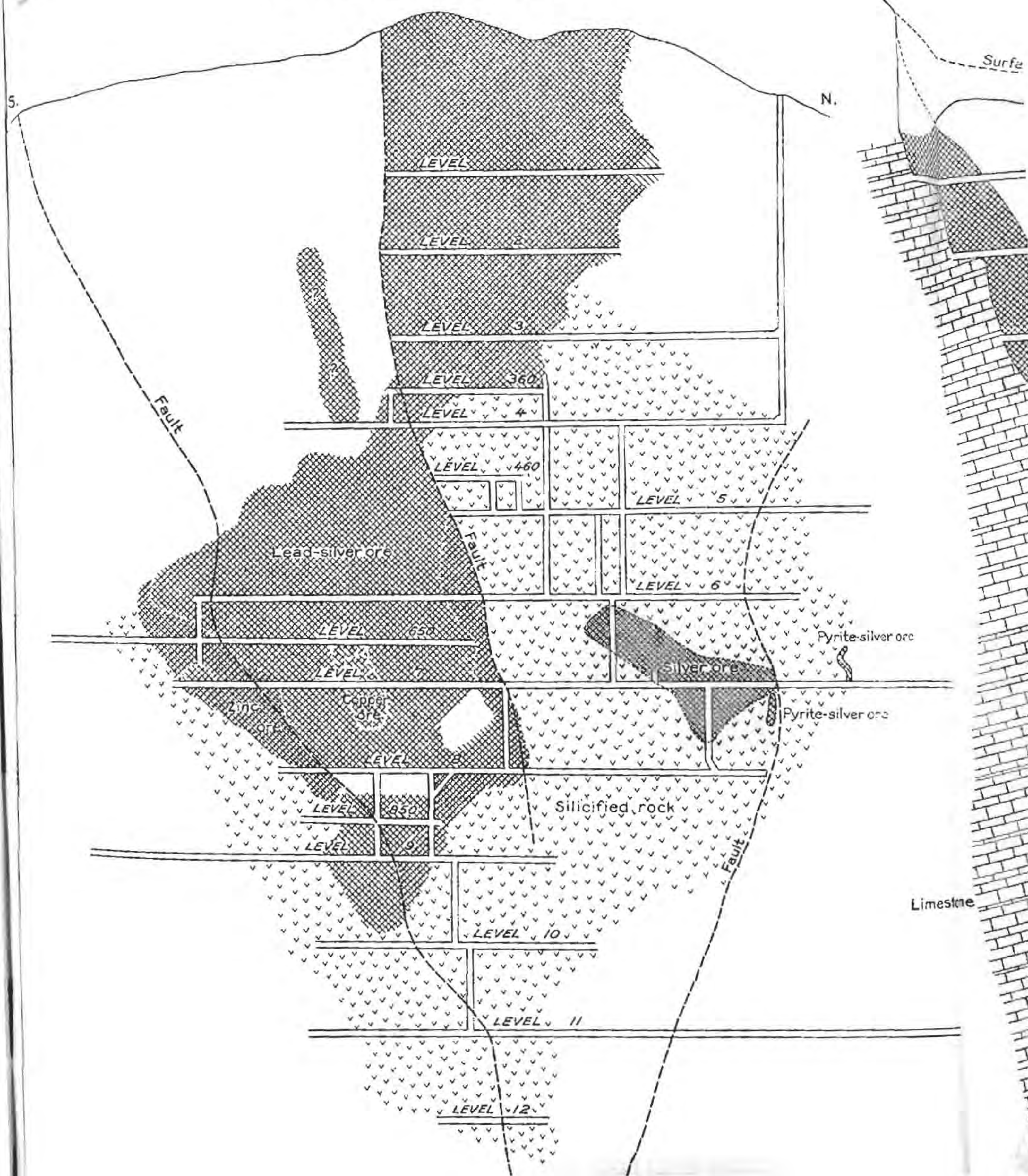


FIGURE 56.—Stereogram showing ore shoot beneath shale. The shoot follows the intersection of the ore fissure and the limestone bed beneath the shale. The ore makes out from the fissure along the limestone bed

posits underlying the Mowitza shale the reason for this selective deposition seems to be largely physical. In the shale the fissures are "tight" and relatively impervious; and the ore-bearing solutions, rising till they came to the stricture, were forced to spread out and replace the more permeable underlying beds. A similar formation of ore bodies beneath shale beds has been noted in several localities in the West. In the Harrington-Hickory mine the chemical composition of the beds has undoubtedly influenced the form of the deposit. The series is made up of interbedded limestone, quartzite, and siliceous shales and limestones. The main ore deposition has been in the limestone, the siliceous beds being very slightly replaced. The characteristic alteration of the limestone adjacent to the fissures is silicification. The most important metals of this class of deposits are lead and silver, though some zinc and copper are present. The de-

[1] Lindgren, Waldemar, Anhydrite as a gangue mineral: Econ. Geology, vol. 5, p. 522, 1910.

LONGITUDINAL SECTION
SHOWING GENERALIZED OUTLINE OF ORE BODIES AND AREAS OF MINERALIZED GROUND



LONGITUDINAL SECTION
NG GENERALIZED OUTLINE OF ORE BODIES AND AREAS OF MINERALIZED GROUND

TRANSVERSE SE

posits have undergone extensive secondary alteration.

TRANSITION DEPOSITS.

Deposits that may be considered transitional are formed like the replacement-fissure deposits, as a replacement of limestone along fissures, but involve the formation of contact minerals such as garnet, magnetite, fluorite, and muscovite. These deposits occur at no great distance from the igneous rock. Such deposits are present in the Wild Bill and Hub mines, where, in fact, they merge into true contact deposits. The Harrington-Hickory and Moscow mines may also be considered of this type, for they contain contact minerals in considerable amount, though as contrasted with the Wild Bill and Hub mines they resemble the replacement-fissure type rather than the contact type. Though the replacement deposits in sedimentary rocks are confined mainly to the limestones or highly calcareous sediments, some ore occurs as a replacement of quartzite and the general relations are similar to those of the deposits in limestone.

MINERALIZATION IN LAVA FLOWS.

GENERAL CHARACTER.

Mineralization of commercial importance in the volcanic rocks is, so far as known, confined to two deposits on the eastern flank of the San Francisco Range—the Horn Silver and the Beaver Carbonate.

The deposits are replacement-fissure veins in which the ore and gangue minerals in part filled open fissures and in part replaced the brecciated rock adjacent to the fissures. In the Horn Silver deposit the ores occur in and adjacent to a strong north-south fault whose displacement exceeds 1,600 feet. In the Beaver Carbonate deposit they lie along an east-west fault of undetermined displacement.

The alteration of the wall rock adjacent to the deposits varies considerably. In the Horn Silver deposit the less intense alteration causes a sericitization of the lavas, and the most intense results in replacements by a finely crystalline quartz containing rather abundant pyrite and some barite. The almost complete silicification of the rock extends 100 to 125 feet from the fissure and in depth persists beyond the lower limit of the ore bodies. (See Pl. XLII.) The limestone which forms the footwall of the deposit has been but slightly silicified. The alteration seems to have affected mainly the permeable brecciated lavas and to have changed the massive limestone but little.

In the Beaver Carbonate mine, on the other hand, the wall rock shows much less intense alteration. The hornblende has been chloritized and the plagioclase partly sericitized, but the orthoclase and biotite show little alteration.

ORE MINERALS.

In the Horn Silver deposit the principal primary ore minerals are galena, pyrite, and sphalerite, and the less important are sulphantimonides and sulpharsenides. The ore minerals occur almost entirely as a replacement of the volcanic rocks and are believed to be essentially contemporaneous in origin. The important primary gangue materials are quartz, barite, and the altered country rock.

In the Beaver Carbonate mine the primary ore minerals are galena, pyrite, and sphalerite, and the principal gangue materials are carbonate, quartz, and the altered country rock. Cherty quartz, sulphides, and calcite, deposited in general in the order named, fill the open spaces between the breccia fragments. The periods of deposition are not sharply defined, however, as some sulphide was deposited with the quartz, some calcite with the sulphides, and a little quartz with the calcite.

ORIGIN OF THE ORES.

All the ore deposits of the region are believed to have been formed during the same general period by solutions having a common origin. This community in origin is indicated by the similarity of the solutions that effected the alteration in the quartz monzonite and in the contact zones in the limestone, and by the fact that the contact deposits grade into the replacement-fissure deposits in the sedimentary rock. The community of these solutions and those that formed the deposits in the extrusive rocks is less clearly shown but is strongly suggested by the general relations of the deposits. A long finger extends from the main body of the quartz monzonite toward the Horn Silver deposit, and is said to reach the Horn Silver fault on the eleventh level. The Beaver Carbonate mine is also in line with the eastward extension of the quartz monzonite body and

the fissures may logically be supposed to reach that rock at depth; in fact it seems highly probable that the fissuring was the result of the intrusion. These relations, though by no means conclusive, certainly suggest a genetic connection. Such a connection for similar deposits is also shown in the Marysvale district to the east.[1]

That the solutions affecting the rocks at different points were exactly the same does not, however, seem probable. As the solutions traverse the rock they are constantly taking up and depositing material; and a solution deficient in a particular element at one point may be rich in that element at some other point. Differences in the character of the rock and in the temperature and pressure may also affect the solutions by checking or hastening deposition. For example, in the contact zones the solutions deposited copper and iron sulphides and only small amounts of lead and zinc sulphides; but in the replacement-fissure deposits, farther from the intrusive mass and under conditions of less heat and pressure, they deposited lead and zinc.

The origin of the ore-bearing solutions is not susceptible of positive proof, but certain facts indicate that the quartz monzonite magma was their original source. The solutions consisted either of meteoric waters that collected their metal content from the rocks through which they circulated, or of magmatic waters that already contain the metallic elements in solution, or of both. Either of them may have been heated—as the depositing solutions unquestionably were; the magmatic solutions would naturally be heated, and the meteoric waters might be heated by contact with the intrusive rocks. Which of them furnished the deposits or was dominant in furnishing them can be inferred from the character of the deposits.

The quartz monzonite (see p. 512) contains aplitic dikes whose composition and relations indicate that they are the siliceous differentiation products of the quartz monzonite. In the bottom of the O. K. shaft what appears to be an aplitic dike contains chalcopyrite and molybdenite as original constituents of the rock, thus seeming to indicate that the sulphides were relatively abundant in the siliceous differentiation product of the magma. In the same mine the "chimney" of quartz with sulphides of copper and molybdenum, which forms the "ore channel," has every appearance of a coarse pegmatite, and it seems reasonable and logical to consider this a further stage in the differentiation of the magma. As the same solutions that carried and deposited the pegmatitic quartz undoubtedly deposited the ore minerals in this quartz and altered the surrounding rock and deposited the sulphides in it they were probably a differentiation of the quartz monzonite magma.

The similarity of the Cactus deposit to that of the O. K. mine leaves no room for doubt that the solutions had a similar origin, though they passed through a more varied cycle of physical conditions, the later minerals of the Cactus deposit not having been formed in the O. K. deposit. Moreover, the presence of tourmaline and copper minerals intimately associated with an aplitic dike on Black Mountain, south of the Cactus deposit, point to the same conclusions concerning the origin of the solutions for this and for the O. K. deposit.

That the ores were deposited during the general period of igneous activity of which the intrusion of quartz monzonite is one phase is indicated by the presence of dikes of kersantite cutting the ore body of the Cactus mine. These dikes are believed to represent a late stage in the differentiation, probably closely following the deposition of the ores.

In the sedimentary rocks the evidence as to the origin of the solutions is most conclusive for the contact deposits. The very close association of the contact ores with the quartz monzonite is in itself suggestive of genetic relation. At the immediate contact at some points a blending of the quartz monzonite and the altered limestone connotes a transition from minerals characteristic of the one to minerals characteristic of the other. This condition is most readily explained by assuming that the altering solutions were given off by the igneous body. It is most natural to extend this explanation to similar deposits where the relation is less close and the solutions may have been of a deeper-seated origin. Further, small fissures that were opened in the altered limestone, probably soon after the intrusion, in the readjustment of stresses, contain veinlets or dikelets of quartz, feldspar, magnetite, and sulphides. These do not differ

[1] Butler, B. S., and Gale, H. S., Alunite, a newly discovered deposit near Marysvale, Utah: U. S. Geol. Survey Bull. 511, 1911.

greatly in composition from the aplitic dikes in the quartz monzonite, and it is most natural to suppose that they had a similar origin—that is, that they were a differentiation from the quartz monzonite magma and indicate the giving off of solutions competent to effect the existing alteration of the limestones. The similarity in the composition of the solutions that effected the alteration in the quartz monzonite and in the limestone also points to a common origin.

The close relation between the different types of deposit in the sedimentary rocks indicates a similar origin for each type, and it is believed that the metal content of all the deposits was derived from the quartz monzonite magma, though it is entirely possible that meteoric waters may have played some part in the formation of deposits at a distance from the intrusive body.

In metal constituents the deposits in the lava flows are similar to the replacement-fissure deposits in limestone, both types being characteristically lead-silver-zinc-copper ores with very little gold. The general relations of the ores in the lava to those in the intrusive rock suggest derivation from the quartz monzonite magma and agrees with observations in other districts. Such an origin for the deposits in this region has, however, not been positively demonstrated.

SECONDARY ALTERATION OF ORES.

GENERAL FACTORS.

The change produced in the mineral deposits of this region by the action of surface solutions has been an important though variable element in the production of the ore deposits as they now exist. It is a striking fact that some of the deposits have been but little affected by such alteration, though the character of neighboring deposits has been completely changed.

The secondary alteration has been dependent on several factors, among the more important of which are the position of the ground-water table, the rapidity of erosion, the physical character of the deposit, and the mineral composition of the deposit. All these factors have doubtless had some effect on each of the deposits, but in several of the deposits some one factor seems to have been dominant.

WATER LEVEL.

The position of the ground-water level has largely determined the limit of secondary alteration in the ore bodies, for alteration has probably not extended very far below this level, though if given sufficient time it would reach this level regardless of other conditions. Other

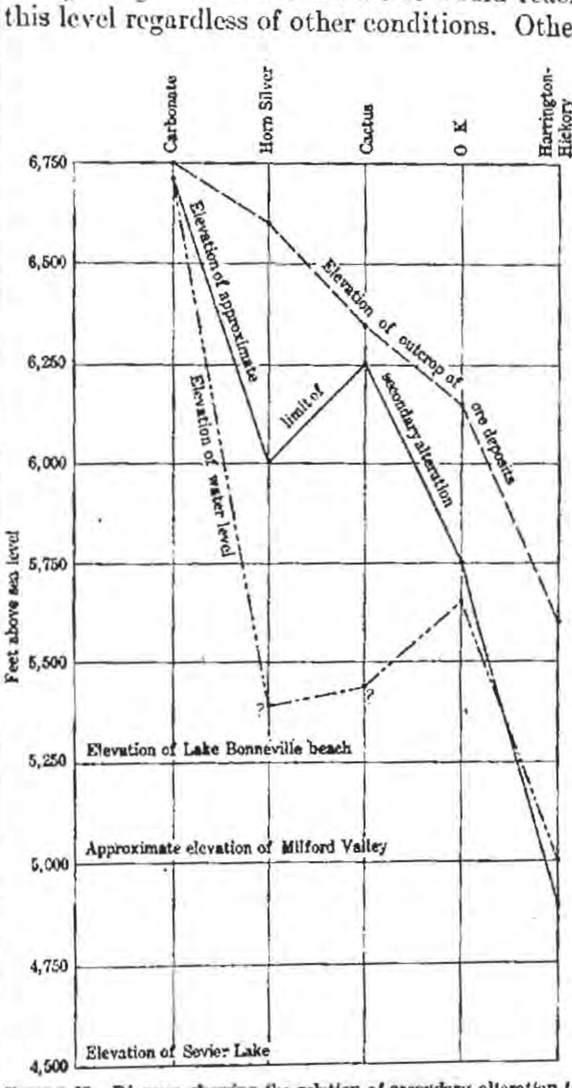


FIGURE 57.—Diagram showing the relation of secondary alteration to outcrop of ore body and to water level in San Francisco and adjacent districts.

factors have been of great importance, however, in determining the rate of alteration.

The water level has been determined in but few mines of the district. Figure 57 shows the elevation above sea level of the outcrop of several of the deposits, the lower limit of important secondary alteration, and the upper limit of the ground-water level (the actual position may be considerably lower).

It is not likely that the water level has remained constant for long periods in the past.

In fact, there are good reasons for believing that it has been both higher and lower than it is now. The beaches of the old Lake Bonneville are about 750 feet above the present surface of Sevier Lake. On the other hand, the great alluvial cones at the mouths of the valleys upon which the Bonneville beaches were deposited testify to a long period of aridity preceding the Lake Bonneville epoch, and it is not unlikely that at that time the water level was lower than at present.

The inability to determine the position of the water level in the past makes it impossible to determine accurately the relation of the water level to secondary alteration, but it is practically certain that in some of the deposits secondary alteration has never reached the ground-water level even in its highest stages. This is especially true of the Cactus mine, where the water level in Lake Bonneville time must have been considerably below the present zone of alteration, and it is doubtless true of the Horn Silver mine also. On the other hand, at the Harrington-Hickory mine oxidized ores are present on the sixth level, 100 feet below the present position of the ground water, indicating a lower water level at an earlier period.

The Carbonate mine is the only one in the region where the present water level and the zone of oxidation show a close relation. In that mine the water level is but slightly below the surface, and this has prevented any extensive alteration of the ore body.

EROSION.

The rate at which the surface is lowered by erosion may be important in determining the extent of the zone of alteration, for if erosion is sufficiently active the altered rock may be removed almost as rapidly as it is formed. There is little doubt that erosion is lowering the surface in the San Francisco Range more rapidly than in some other parts of the area. From this it is to be expected that the zone of alteration will be thinner in the San Francisco Range than, for instance, in the Beavor Lake Range; and comparison of the very similar Cactus and O. K. deposits proves this to be the case. As will be shown later, however, it is thought that the shallowness of the zone of alteration in the Cactus mine is due in part—possibly in large part—to causes other than rapid erosion, although its situation in the bottom of Copper Gulch is favorable to rapid erosion.

PHYSICAL CHARACTER OF DEPOSITS.

It is readily apparent that the physical character of a deposit will have an important influence on the rate at which it will yield to secondary alteration. A massive, dense deposit or one for some other reason relatively impervious to solutions must necessarily alter more slowly than an open, porous one, other conditions being equal. As examples of this difference may be cited massive garnetiferous deposits like that of the Imperial mine, which have suffered relatively superficial alteration, and more open fissure deposits like some of those in the Star district, which have been altered for at least several hundred feet below the outcrop. The influence of the physical condition, however, may be offset by other factors, as in the Cactus deposit, which although open and readily permeable has been only superficially altered.

MINERALOGIC CHARACTER OF DEPOSITS.

The mineralogic character of a deposit may be important in determining both the rate and the character of secondary alteration.

ALTERATION IN QUARTZ MONZONITE.

In the O. K. deposit, to a depth of fully 200 feet, the sulphides, pyrite and chalcopyrite, are altered mainly to hydrous iron oxide and in relatively slight degree to copper carbonates, except in the lower part of the zone, where the carbonates become abundant. Underlying this zone of hydrous iron oxide is a zone of enriched sulphides (covellite and chalcocite) replacing chalcopyrite and pyrite. Beneath the enriched sulphides are primary sulphides.

In the Cactus mine there is a shallow zone in which the sulphides have been altered to hydrous oxides of iron and carbonates of copper, the copper minerals being relatively abundant and the ore showing little loss in copper content. Directly beneath the zone of oxide and carbonate are primary sulpbides. No enriched sulpbides are present.

There seems to be nothing in the physical character of the deposit or in the position of the water table to account for this difference. The relative shallowness of the zone of oxides and carbonates in the Cactus deposit might be explained by the more rapid erosion of the

outcrop; but this in no wise explains the absence of enriched sulphides. The cause for the differences must be sought in the mineral composition of the ores.

The minerals of the O. K. deposit are mainly chalcopyrite and pyrite in a gangue of quartz and muscovite (sericite). The Cactus deposit contains, in addition, important amounts of carbonates (calcium, magnesium, iron, and manganese) hematite, tourmaline, and lesser amounts of anhydrite and barite. There is no reason for believing that the hematite, tourmaline, anhydrite, or barite have affected notably the alteration products resulting from oxidation of the sulphides. The carbonate, however, seems to have been an important factor.

In the O. K. deposit the alteration may be assumed to have taken place in the generally accepted manner, namely, pyrite was oxidized to sulphuric acid and ferrous sulphate, and chalcopyrite to cuprous and ferrous sulphate. The ferrous sulphate upon further oxidation yielded ferric sulphate, which in turn formed hydrous oxide and sulphuric acid, and the acids thus formed assisted in the further oxidation of the sulphide. The copper and iron sulphates were carried to lower portions of the ore body, where the reducing effect of the sulphides on the solutions caused the precipitation of the copper and formed the zone of enriched sulphides.

In the Cactus deposit the sulphuric acid resulting from oxidation of pyrite reacted with the carbonate gangue to form sulphates of lime, magnesia, and iron. The relatively stable lime and magnesia sulphates were deposited or carried out of the ore zone, and the iron sulphate in turn broke down. This process removed the acidic radical in the oxidation process either by depositing it as sulphate or by removing it in solution. The copper sulphate reacted with the carbonate, yielding copper carbonate and sulphates. The relatively stable copper carbonate remained in the oxidation zone. So long as it was abundant it prevented the migration of the copper sulphate solutions to the zone where the copper content would be deposited as sulphide. It seems, therefore, that the abundant carbonate gangue has been the controlling factor in preventing the formation of a zone of enriched sulphide in the Cactus deposit.

SEDIMENTARY ROCKS.

Contact deposits.—Oxidation in the contact deposits has generally been relatively shallow and consists commonly in the formation of carbonates and hydrous oxides and secondary sulphides apparently in a manner similar to that in the Cactus deposit. Where calcite was an important gangue mineral carbonates resulted; where the contact silicates were the main gangue copper migrated downward and formed enriched sulphides. In the subsequent oxidation of the enriched sulphides the oxide of copper is a common product. Much of the ore thus far extracted from the contact zones has been considerably enriched by these secondary processes.

Replacement-fissure deposits.—The replacement-fissure deposits have been extensively altered and primary ores are exposed in relatively few places in the area. Probably, however, they consisted of sulphides of lead, zinc, iron, and copper in a gangue of calcite and quartz and in some places of contact silicates.

The oxidized-ore minerals are mainly limonite, cerusite, small amounts of copper and zinc, usually as carbonates, and still smaller amounts of sulphates, including anglesite and the more complex jarosite and plumbojarosite.

The change that has taken place has been essentially from galena to anglesite and later to cerusite, which is the common lead mineral of oxidized ore, or to some extent has combined with iron in the complex sulphate plumbojarosite. Pyrite has altered to limonite, and chalcopyrite to limonite and copper carbonate. In some places jarosite has apparently been an intermediate product between iron sulphide and limonite. Zinc is present to some extent in the oxidized ores as smithsonite and calamine but has been largely removed from the upper portion of the ore body.

In general it may be said that lead, iron, and copper have migrated only slightly and that sulphur and zinc have been largely removed. Zinc has possibly been deposited at greater depth as carbonate and silicate.

ALTERATION IN LAVA FLOWS.

Zones of alteration.—The Horn Silver and Beaver Carbonate mines are the two important deposits thus far developed within the lava flows. In the Beaver Carbonate mine the

outcrop; but this in no wise explains the absence of enriched sulphides. The cause for the differences must be sought in the mineral composition of the ores.

The minerals of the O. K. deposit are mainly chalcopyrite and pyrite in a gangue of quartz and muscovite (sericite). The Cactus deposit contains, in addition, important amounts of carbonates (calcium, magnesium, iron, and manganese) hematite, tourmaline, and lesser amounts of anhydrite and barite. There is no reason for believing that the hematite, tourmaline, anhydrite, or barite have affected notably the alteration products resulting from oxidation of the sulphides. The carbonate, however, seems to have been an important factor.

In the O. K. deposit the alteration may be assumed to have taken place in the generally accepted manner, namely, pyrite was oxidized to sulphuric acid and ferrous sulphate, and chalcopyrite to cuprous and ferrous sulphate. The ferrous sulphate upon further oxidation yielded ferric sulphate, which in turn formed hydrous oxide and sulphuric acid, and the acids thus formed assisted in the further oxidation of the sulphide. The copper and iron sulphates were carried to lower portions of the ore body, where the reducing effect of the sulphides on the solutions caused the precipitation of the copper and formed the zone of enriched sulphides.

In the Cactus deposit the sulphuric acid resulting from oxidation of pyrite reacted with the carbonate gangue to form sulphates of lime, magnesia, and iron. The relatively stable lime and magnesia sulphates were deposited or carried out of the ore zone, and the iron sulphate in turn broke down. This process removed the acidic radical in the oxidation process either by depositing it as sulphate or by removing it in solution. The copper sulphate reacted with the carbonate, yielding copper carbonate and sulphates. The relatively stable copper carbonate remained in the oxidation zone. So long as it was abundant it prevented the migration of the copper sulphate solutions to the zone where the copper content would be deposited as sulphide. It seems, therefore, that the abundant carbonate gangue has been the controlling factor in preventing the formation of a zone of enriched sulphide in the Cactus deposit.

SEDIMENTARY ROCKS.

Contact deposits.—Oxidation in the contact deposits has generally been relatively shallow and consists commonly in the formation of carbonates and hydrous oxides and secondary sulphides apparently in a manner similar to that in the Cactus deposit. Where calcite was an important gangue mineral carbonates resulted; where the contact silicates were the main gangue copper migrated downward and formed enriched sulphides. In the subsequent oxidation of the enriched sulphides the oxide of copper is a common product. Much of the ore thus far extracted from the contact zones has been considerably enriched by these secondary processes.

Replacement-fissure deposits.—The replacement-fissure deposits have been extensively altered and primary ores are exposed in relatively few places in the area. Probably, however, they consisted of sulphides of lead, zinc, iron, and copper in a gangue of calcite and quartz and in some places of contact silicates.

The oxidized-ore minerals are mainly limonite, cerusite, small amounts of copper and zinc, usually as carbonates, and still smaller amounts of sulphates, including anglesite and the more complex jarosite and plumbojarosite.

The change that has taken place has been essentially from galena to anglesite and later to cerusite, which is the common lead mineral of oxidized ore, or to some extent has combined with iron in the complex sulphate plumbojarosite. Pyrite has altered to limonite, and chalcopyrite to limonite and copper carbonate. In some places jarosite has apparently been an intermediate product between iron sulphide and limonite. Zinc is present to some extent in the oxidized ores as smithsonite and calamine but has been largely removed from the upper portion of the ore body.

In general it may be said that lead, iron, and copper have migrated only slightly and that sulphur and zinc have been largely removed. Zinc has possibly been deposited at greater depth as carbonate and silicate.

ALTERATION IN LAVA FLOWS.

Zones of alteration.—The Horn Silver and Beaver Carbonate mines are the two important deposits thus far developed within the lava flows. In the Beaver Carbonate mine the

water table is near the surface and ore shows comparatively slight alteration. In the Horn Silver deposit the water table is deep, and alteration has been an important factor in the formation of the ore body.

In the Horn Silver mine the important primary minerals of the main ore body are galena, sphalerite, and pyrite, small amounts of jamesonite or some closely allied mineral, chalcopyrite and possibly other copper minerals, argentite, and pyrargyrite or some mineral closely allied to it. Some relatively small bodies (notably to the north of the main shoot on the seventh level) consist mainly of pyrite with small amounts of the other minerals.

The enriched sulphide zone consists of the secondary copper minerals, covellite and chalcocite, and the zinc sulphide, wurtzite, and of the primary minerals in variable amounts.

In the oxidized zone the recognized lead minerals are anglesite, cerusite, plumbojarosite, beaverite, linarite, and bindheimite. Zinc occurs as smithsonite, calamine, and goslarite; copper as brochantite, malachite, azurite, chrysocolla, and chalcanthite, and in lead-copper minerals; silver as cerargyrite; and iron and manganese as hydrous oxides. The characteristic features of the oxidized zone are the great predominance of sulphates, the small amount of oxidized zinc ore, and the small amount of oxidized copper ore, except immediately above the secondary sulphide ore.

Oxidized zone.—Galena, when acted on by surface waters, was altered to anglesite, and as this mineral is relatively insoluble there was little migration of the lead. Some of the anglesite was subsequently altered to cerusite but not in important amounts, as indicated by the following analysis[1] of a representative sample of the ores from the upper levels:

Analysis of Horn Silver ore.

[S. B. Newberry, analyst.]

	Per cent.
Silica	15.17
Sulphate of barium	.49
Sulphate of lead	74.51
Sesquioxide of iron	4.80
Sesquioxide of alumina	1.71
Sulphide of antimony	.37
Sulphide of arsenic	1.12
Lime and magnesia	.50
Carbonic acid	.62
	99.62

Silver (by fire assay, 78.33 [ounces] per ton).

[1] Hooker, W. A., Report to the Horn Silver Mining Co., 1879.

No zinc was found; the quantity is certainly very small and did not show itself, although a special determination was made to ascertain it. The metallic lead, arsenic, and antimony in the ore are as follows: Lead, 50.90 per cent; arsenic, 0.93 per cent; antimony, 0.26 per cent. The amount of moisture in the ore is very small, the average of the run of mine being less than 3.5 per cent, and the sample analyzed above had been thoroughly dried.

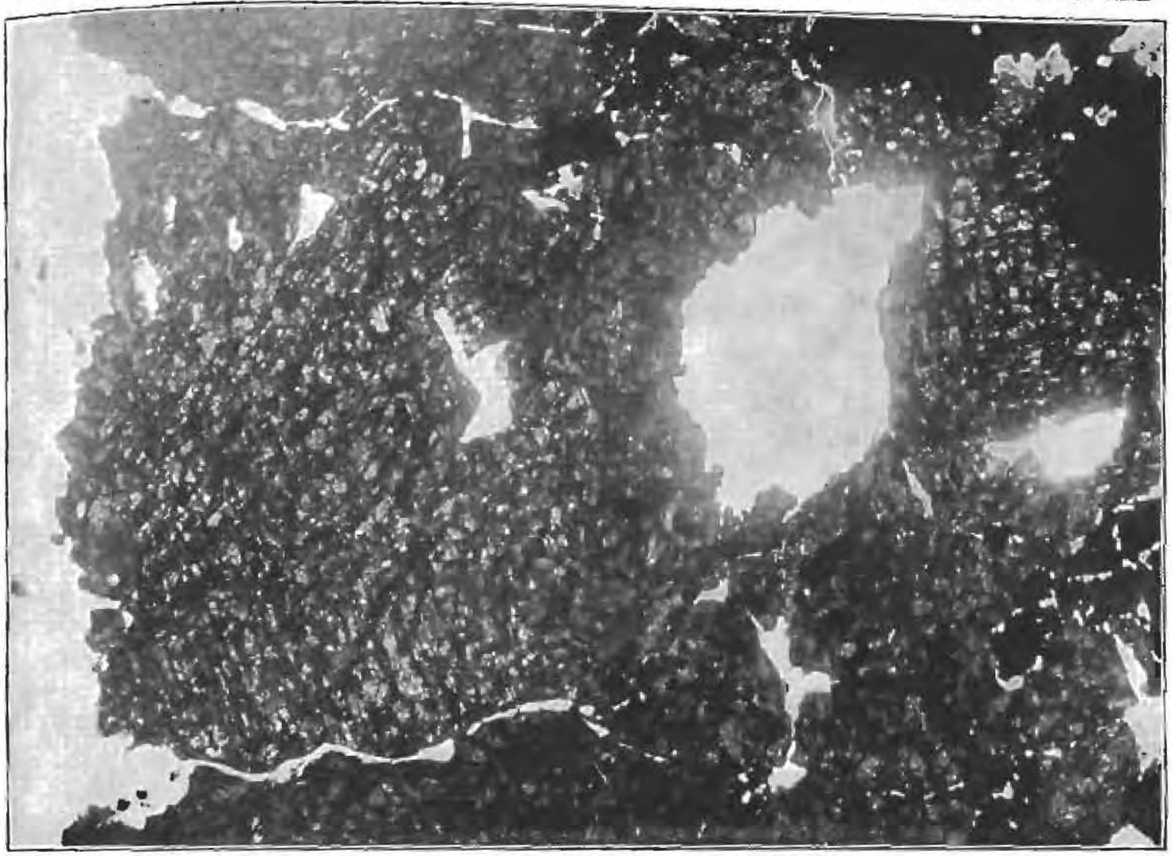
To a relatively slight extent lead entered the complex sulphates beaverite and plumbojarosite.

Sphalerite was likewise oxidized to the sulphate, and this highly soluble material was largely removed from the oxidized zone. The movement of the zinc is amply exemplified at the present time in the lower levels of the mine where the surfaces of zinc ore are frequently covered with festoons of goslarite. To a slight extent smithsonite and calamine were formed and remained in the oxidized zone.

The copper minerals in the zone of oxidation were formed from the alteration of the rich sulphide ores. Chalcocite and covellite alter to brochantite, which is the important copper mineral of the zone; and the brochantite apparently commonly alters in turn to the soluble sulphate, which is carried out of the zone; and thus the oxidized copper ores are kept close to the sulphides. To a slight extent the brochantite alters to carbonate and silicate, but these are apparently eventually acted on by acidic solutions and the copper removed, as indicated by their scarcity in the upper parts of the ore body.

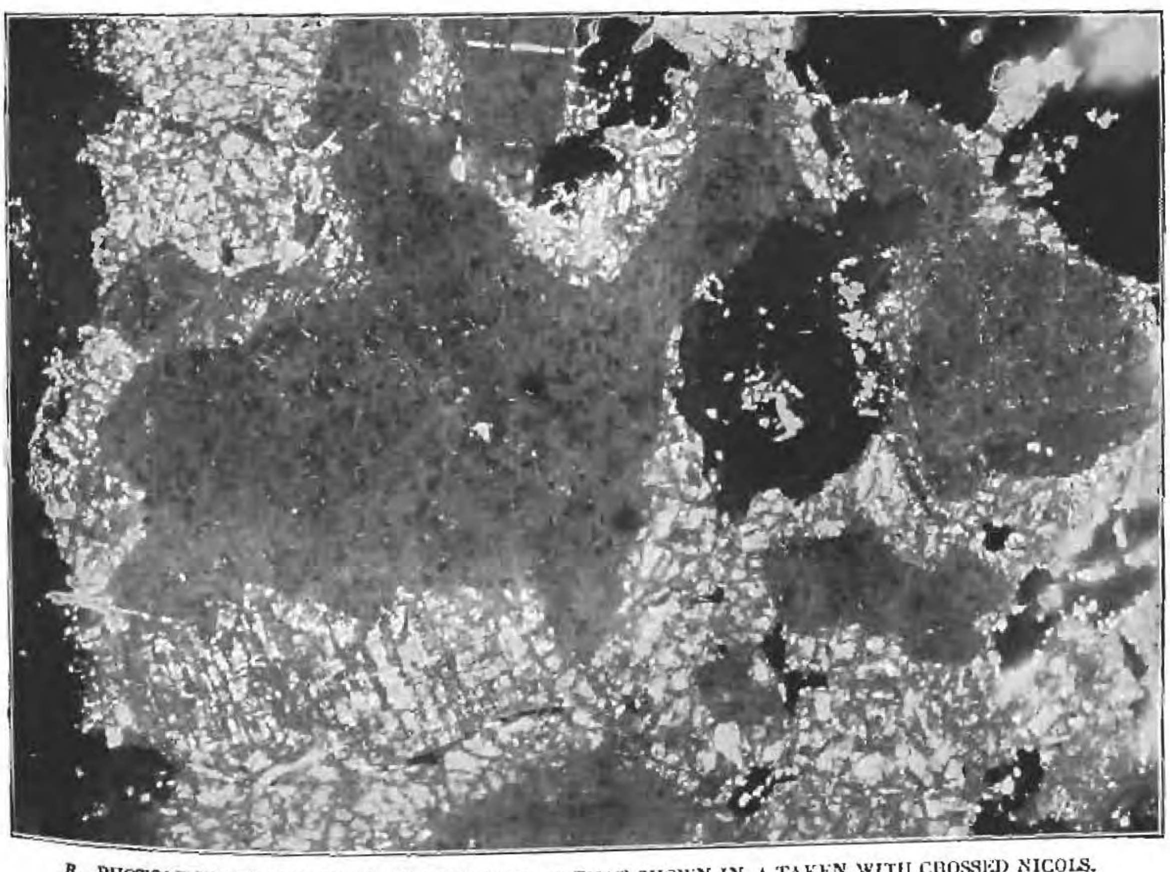
The silver in the argentiferous galena and in other minerals commonly combines with chlorine (probably derived from the salts of the desert) and forms cerargyrite. As silver chloride is only slightly soluble, there has been little migration of silver.

Pyrite has probably altered to ferrous sulphate and sulphuric acid. The ferrous sulphate in part may have altered to ferric sulphate and eventually to limonite and sulphuric acid. In part ferric sulphate evidently combined with other metals to form the relatively insoluble basic ferric sulphates. These, however, eventually broke down, and limonite may have been a resulting product. Much of the iron has been removed, probably as the sulphate. This removal is especially evident where argentiferous pyrite has been altered, the resultant rock being a cellular mass in which the cavities retain the form of the altered pyrite crystals.



A. PHOTOMICROGRAPH OF SPECIMEN OF ZINC SULPHIDES FROM THE HORN SILVER MINE.

Light areas, holes in section; dark areas, galena; gray areas, zinc sulphides. Enlarged 43 diameters.



B. PHOTOMICROGRAPH OF SAME SPECIMEN AS THAT SHOWN IN *A* TAKEN WITH CROSSED NICOLS.

Light areas, wurtzite; gray areas, sphalerite.

Enriched sulphide zone.—In the zone of sulphide enrichment the copper minerals have formed as a replacement of pyrite, sphalerite, wurtzite, and galena. The copper entered the zone as sulphate derived from the alteration of copper minerals above, and, reacted with the sulphides forming zinc and iron sulphates that migrated to some distance. The lead sulphate, on the other hand, apparently remained very close to its place of formation. It is probable that some of the lead sulphate of the higher zone was likewise formed by the reaction of the copper sulphate with galena rather than by simple oxidation. It is equally probable that some of the zinc and iron sulphates were formed by the reaction of lead and copper sulphates with sphalerite and pyrite rather than by oxidation.

The rich zinc ores are those in which wurtzite is relatively abundant. They are largely confined to breccia zones associated with faults, in which the wurtzite very commonly surrounds centers of sphalerite or fills spaces between sphalerite grains. (See Pls. XLII, XLIII.) These relations suggest that the zinc sulphate solutions working downward along the more open channels, namely the brecciated areas, deposited their zinc content around the sphalerite grains. The crystallographic characters of the two sulphides of zinc are very similar, and it seems probable that in many places the sphalerite has controlled the crystallization of the wurtzite. No example of any sulphide being replaced by wurtzite has been noted, and it seems likely that its formation is not comparable to that of covellite as a replacement of sphalerite or pyrite. Most likely it is precipitated by hydrogen sulphide, probably by a method suggested by Allen and Crenshaw.[1]

These investigators find that so far as determined wurtzite is always deposited from an acidic solution. In the oxidation of the sulphides, including pyrite, free sulphuric acid is formed. This reacts in part with sphalerite to form zinc sulphate and hydrogen sulphide and, with these, passes in solution into the sulphide zone. By reaction with the minerals the free oxygen is used up and the acidity reduced, causing the hydrogen sulphide in the solutions to precipitate part of the zinc from the sulphate solution as wurtzite. That the precipitation proceeds much more slowly than that of the copper sulphides is indicated by the much greater vertical extent of the zone of enriched zinc sulphide.

In some of the zinc ores galena has been deposited in both sphalerite and wurtzite, practically certainly as a replacement rather than a simple filling of fissures. It is not believed that this alteration has resulted in any important concentration of lead, but it may have been important in the alteration of the zinc sulphides—that is, the zinc sulphate may have been formed in part by the reaction of zinc sulphide with lead sulphate rather than by simple oxidation, or the action of sulphuric acid or copper sulphate.

No favorable opportunity was observed for the study of secondary silver sulphides, and they are not believed to be important, though they were probably formed to some extent.

Change in metallic content.—Alteration of the ores has worked a change in the metallic content which has been important in determining the commercial value of the deposit.

A record of the ore mined and the metal content by levels, kept for years by the Horn Silver Mining Co., is shown in the following tables:

Partial record by levels of ore and its metal content taken from the Horn Silver mine.

	Total ore.	Lead.	Silver.	Gold.	Copper.
	Tons.	*Tons.*	*Ounces.*	*Ounces.*	*Pounds.*
Cave	2, 888. 338	1, 339. 294	69, 151. 28	14. 877	....
First level	15, 263. 751	5, 644. 161	982, 943. 71	....	....
Second level	47, 667. 035	18, 173. 67	1, 730, 093. 09	....	....
Third level	31, 725. 30	12, 794. 469	1, 062, 755. 91	....	....
Fourth level	5, 351. 818	2, 325. 78	108, 129. 87	....	....
Fifth level	4, 140. 49	1, 363. 89	181, 717. 43	....	....
Sixth level	69, 667. 526	26, 221. 84	1, 823, 067. 08	178. 752	248, 682. 00
Seventh level	26, 796. 815	8, 564. 314	831, 493. 05	306. 713	1, 540, 885. 98
Eighth level	53, 620. 409	18, 327. 163	1, 535, 203. 26	522. 051	858, 433. 28
Ninth level	10, 959. 108	3, 095. 835	250, 823. 24	353. 238	1, 464, 248. 62
	268, 080. 59	98, 150. 415	8, 575, 377. 92	1, 375. 631	4, 112, 249. 88

[1] Allen, E. T., and Crenshaw, J. L., The sulphides of zinc, cadmium, and mercury; their crystalline form and genetic conditions: Am. Jour. Sci., 4th ser., vol. 34, pp. 314-376, 1912. The reader is referred to this important paper for a discussion of the synthetic formation of the zinc sulphides.

Partial record by levels of lead, copper, silver, and gold taken from the Horn Silver mine.

	Lead.	Silver.	Gold.	Copper.
	Per cent.	*Oz. per ton.*	*Oz. per ton.*	*Per cent.*
Cave	46.37	23.94	0.00515	....
First level	36.97	64.39	....	....
Second level	38.12	36.29	....	....
Third level	40.32	33.49	....	....
Fourth level	43.45	20.20	....	....
Fifth level	32.94	43.88	....	....
Sixth level	37.63	26.16	.002565	0.1739
Seventh level	31.91	31.02	.01144	2.873
Eighth level	34.18	28.63	.00973	.80
Ninth level	28.24	22.88	.03223	6.68
	36.61	31.98	.005131	.7669

Unfortunately some of the figures in these tables seem to represent the level from which the ore was hoisted rather than that from which it was extracted. For example, the copper ore that is shown in the tables as coming from the ninth level is stated in another part of the company's report to have come from the seventh and eighth levels.

The following table shows the metal content of several lots of ore taken from the mine:

Metal content of some ores from the Horn Silver mine.

	1	2	3	4	5	6	7
Gold.................ounces per ton..	....	....	(a)	0.013	0.000	0.000	0.013
Silver.........................do....	78.33	51.00	(a)	6.50	5.59	2.83	10.
Lead..........................per cent..	50.00	43.50	8	10	9.41	17.41	11.6
Zinc...........................do....	0.00	0.00	40	35	35.40	(a)	20.7
Iron...........................do....	3.36	(b)	4	2	(a)	(a)	5.3
Silica.........................do....	15.7	(b)	20	35	(a)	(a)	35.4
Sulphur........................do....	....	(b)	28	15	(a)	(a)	18.0
Copper.........................do....	....	....	....	....	....	23.7	....

a Not reported. b Not estimated.

1. Oxidized ores. Analyses from report by W. A. Hooker.
2. Average of all ores to 300-foot level as determined by Hooker.
3. Average yield of 500 tons of zinc ore from seventh level. Emmons, S. F., Am. Inst. Min. Eng. Trans., vol. 31, p. 658, 1902.
4. Approximate average of zinc ore from 700-foot level, by M. C. Morris, general manager. The sulphur is evidently too low, as it is not sufficient to combine with the metals to form sulphides, though the analysis sums practically to 100 and other general analyses and the study of the ores show that the metals are present as the sulphides.
5. Average of zinc ore shipped in 1905, from company's report.
6. Average of copper ore shipped in 1904, from company's report.
7. Average of shipment of zinc-lead ore from 900-foot level; figures furnished by M. C. Morris, general manager.

So far as the statistics included in these tables are concerned the oxidized zone may be considered as including the first five levels. The average metal content recorded from these levels is lead 38.99 per cent and silver 38.63 ounces per ton. The average in lead and silver of ores hoisted from the ninth level (largely primary) was silver 22.88 ounces per ton and lead 28.24 per cent; and the average of certain shipments of primary zinc-lead ore from the 900-foot level shows silver 10 ounces per ton, lead 11.6 per cent, and zinc 20 per cent. The average of all ores mined has been lead 33.61 per cent and silver 32.04 ounces per ton. It is evident from these figures that the ores in all parts of the main ore body show a definite relation between lead and silver content of approximately an ounce of silver to each per cent of lead.

If an ore similar in composition to those of the lower levels, which are regarded as essentially primary, should have all the zinc sulphide and a part of the iron removed and the silica content reduced to 15 per cent (as low as that in the analysis on p. 524) the resulting product would be comparable to the average of the oxidized ore. It is evident, therefore,

that the lead and silver content of ore in the oxidized zone has been materially increased by the process of alteration and that the zinc and copper have been largely removed.

In the relatively small silver-ore bodies there has been a marked increase in silver content, due to the removal of iron sulphide.

In the zone of sulphide enrichment the zinc content of much of the ore has been raised from probably 20 to 25 per cent to 35 per cent or more. This increase has been due to an addition of zinc sulphide and possibly, to a lesser extent, to the removal of other constituents.

As the primary ore carries only a small percentage of copper, there has evidently been a marked addition of this metal in the enriched sulphide zone.

In the rich zinc ores there has been a relative decrease in lead due to the addition of zinc, so that these ores contain a lower percentage of lead than either those of the primary zone or the oxidized zone.

The process of alteration has resulted in the enrichment of the oxidized zone in silver and lead. Primary ores only moderately rich in these metals have been changed to high grade. In the zone of sulphide enrichment material that was too low in zinc to be profitably mined under ordinary conditions and material that contained very little copper have been converted into ores.

WAH WAH RANGE.

By B. S. Butler.

The following notes are the result of a two-day reconnaissance by the author across the Wah Wah Range at Pine Grove Canyon and at Wah Wah Pass. The portion of the range north of the Wah Wah Pass was not examined.

GENERAL FEATURES.

The Wah Wah Range is a prominent north-south range of southwestern Utah extending from 38° to 39° north latitude. It is the range next west from the San Francisco Range, lying between Preuss or Wah Wah Valley on the east and Sage Brush Valley on the west. It attains elevations of 9,000 feet (estimated) but for the most of its extent is 1,000 to 2,000 feet lower. In general its eastern slope is relatively gentle and its western slope abrupt. The range is divided into two nearly equal parts by the low Wah Wah Pass, which is traversed by the road from Newhouse to Osceola and Ely, Nev.

Water is scarce, the supply being derived from springs and small streams that sink into the gravels as soon as they leave the mountains. Both springs and timber are, however, more abundant than in many of the desert ranges. The water supply for Newhouse is derived from springs in the range.

GEOLOGY.

SEDIMENTARY ROCKS.

The range is made up largely of sedimentary rocks, though both intrusive and extrusive rocks are present. The lowest formation exposed is a massive red quartzite which forms a large part of the range south of Pine Grove Canyon but which gradually dips below the surface to the northward and is not present north of Wah Wah Pass. The Red Buttes, just south of Wah Wah Pass, at the west base of the range, are the most northerly portion of the quartzite observed. Overlying the quartzite in the vicinity of Pine Grove Canyon are shales and shaly limestones with an estimated thickness of 800 to 1,000 feet. The shale series is overlain by massive limestone and dolomitic limestone having a thickness of several thousand feet. In the latitude of Wah Wah Pass and northward this limestone series makes up the bulk of the range.

Fossils collected from the upper portions of the limestone series on the Pine Grove road and to the east of Wah Wah Pass and from the shale series overlying the quartzite in Pine Grove Canyon were reported on by L. D. Burling as follows:

> Lot 2.—Shale series, Pine Grove Canyon, Middle Cambrian, containing *Ptychoparia* sp. and *Bathyuriscus* sp. This fauna is characteristically found in limestone bands in shale in the lower part of the Middle Cambrian only a few hundred feet above the top of the quartzite series, in several of the ranges of western Utah.

The collections from the limestone contained *Crepicephalus texanus*, *Agraulos* sp., and *Ptychoparia* sp. Of these Mr. Burling says:

> The specimens of *Crepicephalus texanus* are hardly to be distinguished from specimens of the same species occurring in Middle Cambrian limestone in Tennessee and Alabama. The same species occur in both the Orr formation (Upper Cambrian) and the Weeks limestone (Middle Cambrian) of the House Range, Millard County, Utah. It is associated in the Orr formation with *Illaenurus* and *Ptychaspis*, species which are absent in the Weeks formation.

The fossil evidence in limestone and shales, together with comparison with sections elsewhere, indicates that the limestones are probably of Middle to Upper Cambrian age.

IGNEOUS ROCKS.

EXTRUSIVE ROCKS.

Along the eastern base of the range and extending partly up the eastern slope are heavy-bedded volcanic flows. South of Pine Grove Pass they reach the summit of the range and apparently form a much larger proportion of it than they do farther north. As exposed in Black Canyon on the Pine Grove Road the lowest beds are gray trachytic-looking rocks containing rather abundant phenocrysts of plagioclase, hornblende, biotite, and a few of quartz. The groundmass, forming a large percentage of the rock, is glassy. The composition is probably that of latite or possibly andesite. Overlying the gray lavas are flows that weather to a dark reddish brown. These contain a much larger proportion of glass than the underlying lavas but probably do not differ from it greatly in composition. The uppermost flows observed are rather fine grained andesite containing abundant phenocrysts of plagioclase and augite in a groundmass of glass and microscopic crystals of plagioclase and augite. Magnetite is rather abundant. The rock is a typical augite andesite.

INTRUSIVE ROCKS.

No large bodies of intrusive rock were observed or are reported from the range. Small intrusive masses were seen near the summit at Wah Wah Pass and in Pine Grove Canyon on the west side of the range and are possibly present at other places. The intrusive rock at Wah Wah Pass outcrops as irregular masses, but the dome structure of the range at this point and the alteration of the limestone suggests that much larger bodies are present at no great distance below the present surface. The rock is a dark fine-grained porphyry probably of monzonitic or dioritic composition.

In Pine Grove Canyon a dikelike body of granite porphyry probably 1,000 feet wide is exposed along the strike for several thousand feet. It is a fine-grained rock containing rather abundant phenocrysts of quartz and orthoclase and fewer of plagioclase in a groundmass too finely crystalline for its mineral composition to be definitely determined. Several small dikes noted in the Pine Grove district are so highly altered that their original composition can not be determined, but in general they are similar to the larger intrusive body, though some of them at least contain considerable biotite and much less quartz.

STRUCTURE.

The range is typical of the Basin Range type of mountains, being composed of a block that has been faulted along its western front and uplifted so that the beds dip east.

The strike of the beds is in general parallel with the range but inclined sufficiently to the southeast to lift the quartzite from Wah Wah Pass to Pine Grove Canyon several hundred feet above the base line of the mountains. The dip of the beds varies considerably; at Pine Grove it is about 45°, but north of Wah Wah Pass the strata seem from a distance to be nearly horizontal.

At Wah Wah Pass the rocks have a gentle dome structure which has possibly resulted from the intrusion of an igneous mass that is just being uncovered. The doming of the rocks has rendered them particularly susceptible to erosion at this point and resulted in the formation of the low pass.

East-west faulting was noted especially in Pine Grove Canyon, whose lower course it apparently determines. The movement has apparently been at least 1,000 feet, with downthrow to the north. Careful study would doubtless show many small faults and probably other large displacements.

The only production from the range has been lead ore from the Pine Grove district and some iron from near English Springs. A little prospecting has been done on the east side of the range a few miles south of Pine Grove Pass and in the latitude of Wah Wah Pass.

PINE GROVE DISTRICT.

ACKNOWLEDGMENTS.

The writer wishes to acknowledge courtesies by the Revenue Mining Co. A geologic map of the company's property prepared by Mr. C. C. Jones was furnished by the company and was of great aid.

GENERAL FEATURES.

The Pine Grove district is on the west side of the Wah Wah Range about 18 miles southwest of Newhouse, the nearest railroad point. The

shortest route from Newhouse leads nearly southwest across Wah Wah Valley and thence westward over a rather high pass. A road with better grades crosses the range at Wah Wah Pass and thence follows the western front south to Pine Grove Canyon. Heavy grades are encountered on each route, both going and coming.

The district was organized in 1873, but no work was done until it was reorganized in 1879. There were in 1880 about 20 locations. Little has been done except by the Pine Grove Consolidated Mining Co. and the Revenue Mining Co. A mill was constructed in the district but has not been operated. It is reported that a little ore was shipped from the district in the early days.

Pine Grove Creek furnishes a small flow of water throughout the year. Timber is present in sufficient quantity to supply any likely demands for some time to come.

ORE DEPOSITS.

The rocks of the district have been cut by a series of fissures striking about northwest. Slight displacements along the fissures have crushed the quartzite adjacent to the fissures and have formed breccia zones. The fissures in the limestone are less conspicuous, as the character of the rock was not favorable to the formation of breccia.

The most extensive prospecting has been done on the fissures or breccia zones in the quartzite. The primary ore, mainly galena with some pyrite, occurs as a filling between the breccia fragments and possibly to some extent as a replacement of the quartzite. The deposits occur as small lenses, many of which are near one wall of the breccia zone. Near the surface the galena has been altered to sulphate and carbonate of lead and the pyrite to limonite.

The rock adjacent to the fissures in the limestone has in places been partly replaced by galena and pyrite. These minerals have been oxidized near the surface but not to the same extent as the deposits in quartzite.

The developments in the district and the time given to the study do not warrant any very positive statements concerning the origin of the ores. No very intimate relation between the ore deposits and either the granite porphyry body or the small dikes has been observed, but comparison with other districts suggests that the deposition of the ores was due to the igneous activities.

At the time of visit little material that under present conditions could be regarded as ore was exposed in the prospect openings.

WAH WAH PASS REGION.

Prospecting in the vicinity of Wah Wah Pass has been confined to a few shallow pits and trenches. Fair assays are reported but have apparently not been sufficiently encouraging to lead to extensive prospecting.

ENGLISH SPRINGS.

The iron deposits in the eastern foothills of the Wah Wah Range near English Springs, about 20 miles west of south from Newhouse, were not examined, and no description of them has been found in the literature. Some ores from them were shipped to the Frisco smelters about 1880.

INDIAN PEAK DISTRICT.

The Indian Peak district is in the Needle Range, in the western part of Beaver County, about 35 miles north of Modena and about the same distance from Lund, on the Los Angeles & Salt Lake Railroad. There has been some prospecting in the district for many years and there has been a small production of lead and silver.

The district was not visited by the writer and no description of the geology has been found in the literature. The ore deposits are said to be replacements of limestone adjacent to fissures.

MINERAL RANGE.[1]

By B. S. Butler.

GENERAL FEATURES.

The Mineral Range extends a little east of north across Beaver County between Milford Valley on the west and Beaver Valley on the east. The principal railroad point is Milford, on the Los Angeles & Salt Lake Railroad, about 7 or 8 miles west of the central part of the range and 10 to 25 miles by road from the principal mineralized areas. (See fig. 58, p. 532.)

The central part of the range is rugged, rising to an elevation of 11,000 feet and being cut by narrow canyons that render travel

[1] Report based mainly on a reconnaissance of the range in the summer of 1910.

difficult. Beaver Canyon is a low pass, which is utilized as a transportation outlet for Beaver Valley and the east side of the range. South of Beaver Canyon the range is much lower, the slopes usually gentle, and travel much easier.

Water is scarce, but enough for the needs of prospectors can usually be developed without going a great distance from the prospect. In many parts of the range juniper (cedar), piñon, oak, and other scrubby trees furnish a rather abundant fuel supply and are used to some extent for timbering. There is good timber in the range east of Beaver. The irrigated lands along Beaver Creek furnish abundant farm products. Electric power for mining can be had from the plant on Beaver Creek.

HISTORY AND PRODUCTION.

By V. C. Heikes.

The range contains the Lincoln, Bradshaw, Granite, North Granite, McGarry, Antelope, and Jarloose districts.

LINCOLN DISTRICT.

The Lincoln district, organized January 16, 1871, is in Beaver County on the eastern slope of the Mineral (Granite) Range, 20 miles southeast of Milford, on the Los Angeles & Salt Lake Railroad, and 4 miles north of Minersville, the supply point and settlement. It adjoins the Bradshaw district on the southeast corner. The district was first called Pioneer district and was organized in 1864. According to Fabian,[1] "the Mormons commenced working the old Spanish mine as far back as 1854, which has since been named the Rollins lode. The other principal claims in the district are [1872] the Quincy, Alameda, Wasatch, Lewis Grundy, Creole, Galena, and St. Cloud."

Eissler [2] says:

The first "parcel" of silver-lead ore on the Pacific coast was smelted by a Mormon named Isaac Grundy, back in the fifties.

When Brigham Young learned that Johnston's army was coming to Utah he sent Grundy down to Beaver County to obtain material for leaden bullets to be used against the coming army. Grundy went to what was afterwards known as the Rollins or Lincoln mine, and getting out ore he smelted in a small furnace several tons of bullion, which was sent to Salt Lake City and there molded into bullets. Grundy may be considered, therefore, as the pioneer of the metallurgy of lead on the Pacific coast; and I have just learnt (August, 1891) that he died only a few weeks ago at Minersville, Utah, at the age of 80.

[1] Fabian, Bentham, The resources of Utah, p. 14, Salt Lake City, 1872.

[2] Eissler, M., The metallurgy of argentiferous lead, preface, 1891.

The Rollins lode was operated again between 1860 and 1863. Ore was smelted in this district, and it is said that some lead ore was shipped to Omaha for reduction. Huntley[3] says:

The principal claim in the district is the old Rawlings or Rollins mine. It is claimed by the Mormons that it is the oldest mine in the territory. They worked it in 1860, 1861, 1862, and 1863, and made a few tons of lead in a primitive way. The mine was sold in 1875 to the Lincoln Silver Mining Co. A 15-ton furnace was built in the fall of the same year. The company worked both the mine and the smelter for two years. * * * The incline was sunk 220 feet, and showed a 6-foot vein at the bottom. One-fourth of this was pyrites and the remainder galena. In the upper works the ore body was from 8 to 12 feet wide. The average assay of the ore was $40 silver and $15 gold. About 100 tons of bullion, worth $165 per ton, were produced.

The December group of mines had been recently sold to the December Mining Co. of Chicago. The principal vein is from 1 foot to 4 feet wide, carrying a smelting ore which assays $100 per ton when selected. A few tons have been shipped. There are 200 feet of cuttings.

The Coral Reef, Yula, and Richmond are a group on one vein, said to be from 3 to 5 feet wide, containing a low-grade smelting ore, 20 ounces silver, 30 per cent lead, and some zinc blende and pyrite. * * * About 80 tons had been sold formerly.

No statistics are available of any of the properties producing in the Lincoln district between 1880 and 1901. In 1907 the Lincoln or Rollins mine was reopened, but it is not known what was found in the lower levels. The Survey has no record of shipments from the property.

About 200 tons of low-grade fluxing iron ore, carrying values in gold, silver, and copper, was taken from the Creole property in 1907, and several shipments of lead ore have been made from the Harriet claim. All production has been included with that of Beaver County. (See pp. 506–507.)

BRADSHAW DISTRICT.

The Bradshaw district, in Beaver County, organized May 1, 1875,[4] adjoins the Lincoln district on the north, and is about 10 miles southeast of Milford, on the Los Angeles & Salt Lake Railroad. Huntley says:[5]

The Cave mine, the principal mine of the district, is about 8 miles southeast of Milford and northwest of Minersville on a steep mountain side, about 4,300 feet above the

[3] Precious metals: Tenth Census U. S., vol. 13, p. 475, 1885.

[4] Record in office of U. S. surveyor general, Salt Lake City, Utah.

[5] Op. cit., pp. 474–475.

Beaver River, and over 6,000 feet above sea level. The cave in which the mineral was first found was discovered in 1859. * * * It was not located, however, until 1871. Little was done until 1875 and 1876, when some ore was worked at the Milford mill. The mine became financially involved * * * and in September, 1879, the mine became the property of the Frisco Mining & Smelting Co.

In places the ore has been very rich, assaying as high as \$500 to \$800 per ton. Ore of the lowest grade assays \$5 in gold and silver. All the limonite and ocher, without regard to its grade, was shipped to the smelter at Frisco, it being worth from \$8 to \$10 for flux alone. The average grade of all the ore shipped could not be ascertained, but for several hundred tons recently shipped it was given at from 5 to 7 per cent lead, \$22.50 silver, and \$7.50 gold per ton. * * * The total assay value of the ore produced prior to June 1, 1880, was estimated at \$270,000, one-quarter of which was gold.

The Jolly Boy is in the northern part of the district, and was discovered in the fall of 1879. * * * Four tons of selected ore, a soft ocher, averaged \$12 silver and \$333 gold.

The Cave mine is reported by its owners to have been an occasional producer between 1880 and 1900. Since 1900 it has yielded about 1,400 tons of low-grade oxidized iron ore. In 1908 the Hecla produced ore containing gold, silver, lead, and a little copper.

GRANITE AND NORTH GRANITE DISTRICTS.

The Granite and North Granite mining districts, organized in 1863 and 1865, are in Beaver County, northeast of the Lincoln district and northwest of Beaver. According to Huntley,[1] the bismuth property on the east side of the range attracted the most attention:

It was discovered about 1865 * * * and known (August, 1880) as the Major lode. The vein is 5 to 7 feet wide and contains a tough quartz or gangue. In this, some pyrite, galena, and, it is said, 3 per cent of bismuth are found. A few tons were shipped years ago, and were said to have averaged from 7 to 10 per cent bismuth.

In several parts of the district there are signs that some oxidized iron ore was produced and hauled, probably to the Frisco smelter, in the eighties. In the last decade small quantities of low-grade copper and lead ores have been shipped, but the returns barely paid expenses of shipment and treatment.

M'GARRY AND ANTELOPE DISTRICTS.

The McGarry and Antelope districts, at the north end of the range on the western slope were organized in 1876 and 1877 but have produced little metal.

[1] Op. cit., p. 475.

JARLOOSE DISTRICT.

The Jarloose district is in the volcanic area, a few miles southeast of Minersville. Numerous "strikes" have been reported, but thus far there has been no important metal production and but little prospecting.

PHYSIOGRAPHY.

By B. S. Butler.

The Mineral Range is to be classed with the Basin Range type of mountain, though in its present stage of physiographic development it is not as typical as some of the ranges of the State. In general, however, it shows a nearly straight western front determined by faulting, a relatively steep western slope, and a gentler eastern slope. The portion of the range south of Beaver Canyon is composed of relatively weak lavas and is more mature topographically; and the fault-block structure is much less apparent. Morever, the uplift of this portion of the range is much less, as it is separated from the northern part by an east-west fault in the latitude of Beaver Canyon.

GEOLOGY.

SEDIMENTARY ROCKS.

Sedimentary rocks are largely confined to the area north of Beaver Canyon where, except for a space on the west side, they surround the central mass of intrusive rocks. (See fig. 58.) Lee[2] gives the following section of the rocks as exposed in Beaver Canyon:

Section of rocks exposed in Beaver Canyon, 4 miles east of Minersville.

	Feet.
1. Basalt, several hundred feet.	
2. Rhyolitic flows, tuffs and breccia, many hundred feet.	
3. Andesitic flows, tuffs and breccia, several hundred feet.	
4. Uncemented gravel and boulders of limestone, quartzite, and andesite	250
5. Coarse consolidated conglomerate consisting of limestone, quartzite, and various crystalline rocks, the boulders having a maximum diameter of 5 feet	90
Unconformity.	
6. Red shale	60
7. Earthy-gray limestone	15
8. Red shale	10
9. Gray limestone	10
10. Red shale and ripple-marked sandstones	40

[2] Lee, W. T., Water resources of Beaver Valley, Utah: U. S. Geol. Survey Water-Supply Paper 217, p. 10, 1908.

	Feet.
11. Blue limestone	10
12. Red shale and ripple-marked sandstones	120
13. Limestone containing *Aviculipecten weberensis*, *Aviculipecten* aff. *A. occidentalis*, *Myalina* aff. *M. perattenuata*, *Bakewellia* n. sp., *Pleurophorus* sp., *Schizodus* sp	15
14. Shale	40
15. Limestone containing same fossils as No. 13	15
16. Buff shale with a subordinate amount of limestone	95
17. Shale and limestone containing *Aviculipecten* n. sp., *Pleurotomaria?* sp., *Bakewellia* n. sp., *Naticopsis* sp., *Xenodiscus?* sp., undetermined ammonoids	100
18. Red shale	35
19. Yellowish-brown shales alternating with ripple-marked sandstones	40
20. Quartzitic basal conglomerate	10
Unconformity.	
21. Cherty limestone containing *Zaphrentis?* sp., *Fistulipora* sp., *Septopora* sp., *Productus* aff. *P. subhorridus*, *Meekella?* sp., *Spirifer* aff *S. cameratus*, *Squamularia* aff. *S. perplexa*, *Spiriferina* aff. *S. kentuckyensis*, *Spiriferina* sp., *Composita* aff. *C. subtilita*, *Hustedia* aff. *H. meekana*, *Pugnax* aff. *P. osagensis*	450
22. Yellowish quartzite	200
23. Cherty limestone containing *Squamularia?* sp. and *Hustedia* aff. *H. meekana*	500
Base not exposed where section was measured.	

Concerning the sedimentary rocks, Lee says:

A thick series of massive limestones overlies the granite and is well exposed in the Mineral Mountains north of Minersville. These limestones are overlain in turn by red sandstones, shale, and volcanic products, as shown in the section.

The massive cherty limestone at the base of the section is referred with little doubt to the Aubrey. The fossils were examined by George H. Girty, of the United States Geological Survey, who states that they probably belong in the Aubrey fauna, although many of the most characteristic forms of the fauna are wanting. The stratigraphic position and general field relations of the limestone show that it is probably the same as the typical Aubrey limestone of the Grand Canyon region farther to the south.

The red sediments overlying the cherty limestone yielded a number of well-preserved fossils which also have been examined by Dr. Girty, who states that the fauna is the same as that of the Permian beds of Walcott's[1] Grand Canyon section and of the "Permo-Carboniferous" of the Wasatch Mountains.

In Colob Plateau, about 50 miles south of Beaver, a thickness of more than 8,000 feet of strata was measured between the base of the Permian and the top of the Benton. Of this great thickness only 565 feet of the base of the Permian remain in Beaver Canyon, the upper beds having been eroded away. The red beds are overlain by a coarse conglomerate, presumably equivalent in age to the Eocene conglomerates of the plateaus, and these are covered in turn by extensive masses of volcanic rock.

The section apparently corresponds with the upper part of the Carboniferous and the lower part of the Triassic, as exposed in the Star district to the west.

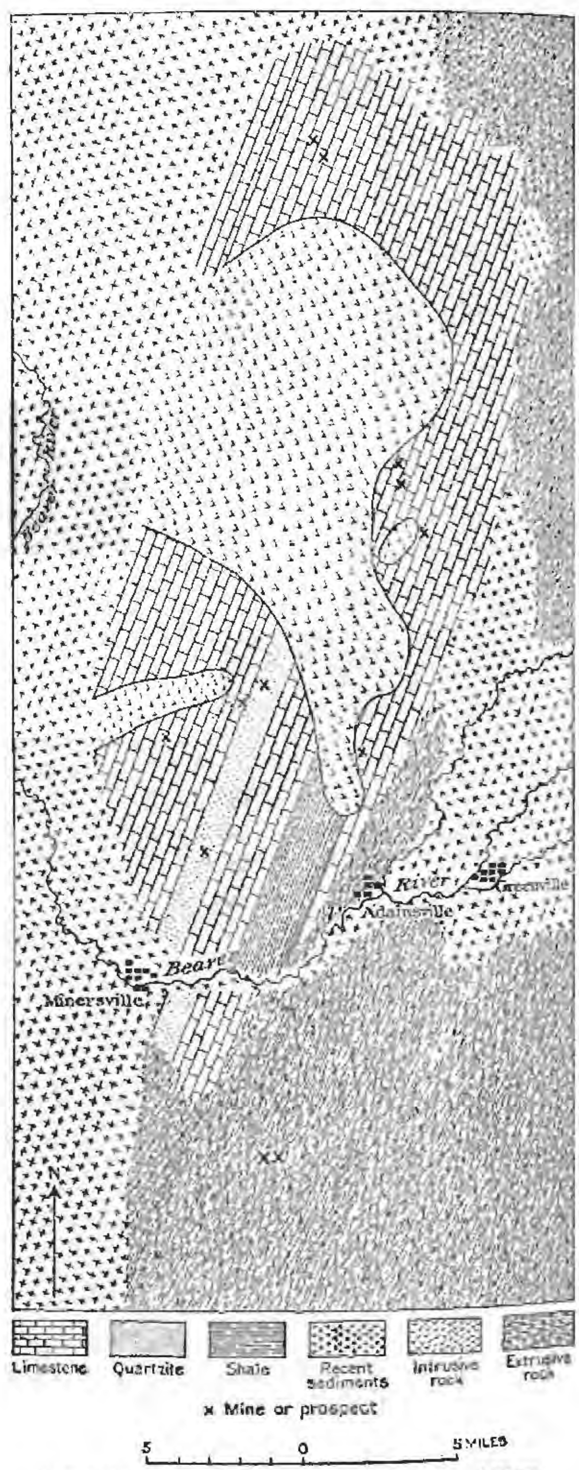


FIGURE 58.—Reconnaissance geologic map of Mineral Range.

The sedimentary rocks at the northern end of the range apparently correspond to the lower portion of the section given above.

[1] Walcott, C. D., The Permian and other Paleozoic groups of the Kanab Valley, Ariz.: Am. Jour. Sci., 3d ser., vol. 20, pp. 221, 225, 1880.

IGNEOUS ROCKS.

INTRUSIVE ROCKS.

The main body of the intrusive rock forms the central portion of the range. It has a north-south extension of about 15 miles and a width of 4 to 8 miles. This main mass was examined in but few places and only general statements as to its character are warranted from the facts gathered. It is a light-colored granitic rock varying considerably in texture and probably in composition. Specimens believed to be representative are rather coarse grained and are composed largely of quartz, orthoclase, microcline, plagioclase, and biotite. Orthoclase and microcline are greatly in excess of plagioclase, and the rock is a true granite. Both north and south of the main mass, and possibly within it, are small bodies of more basic rocks of monzonitic and dioritic composition.

Bodies of fine-grained granite porphyry, similar in composition to the main body of the granite, occur also in the sedimentary rocks. At the east base of the north end of the range there are outcrops of a coarse granitic rock overlain by recent basaltic flows. The relation of this to the main intrusive body of the range was not determined.

In addition to the larger intrusive bodies mentioned, numerous dikes cut both the sedimentary and intrusive rocks. They are fine grained, usually not distinctly porphyritic, and when freshest are dark green. Most of them have the composition of diorite, though some are more basic. These dikes weather readily to a brown earthy mass, and as they are usually less resistant than the surrounding rocks, they are not conspicuous at the surface.

EXTRUSIVE ROCKS.

Extrusive rocks are most important south of Beaver Canyon, where they form a large part of the range, and in Beaver Valley east of the range. The volcanic rocks range from rhyolites to basalts, but a large proportion are of intermediate composition near latites. The latest flows are cellular basalt, which cover large areas east and northeast of the range.

RELATION OF THE INTRUSIVE AND EXTRUSIVE ROCKS.

The intrusive rocks were nowhere seen in contact with the main body of extrusive rocks and their relative age has not been determined. In the Tushar Range to the east the intrusive rocks are later than the main extrusive body, and the same relation may exist in the Mineral Range. The basaltic flows are very recent and represent the latest igneous activity of the region.

STRUCTURE.

The present attitude of the sedimentary rocks is due in part to the effects of the granitic intrusion and in part to later movements. South of the granitic mass they strike north to northeast and dip east. To the north of the granitic mass the strike and dip are irregular but are probably prevailingly to the west.

Faulting is believed to have been important in producing the Mineral Range. It is believed that the front of the range is determined by a strong north-south fault with downthrow to the west.

A short distance south of Beaver Canyon the sedimentary rocks are buried beneath lavas and are at much lower levels than to the north. There is apparently a strong east-west fault near the site of Beaver Canyon, though its exact location was not determined.

Fissures are numerous and have been of importance in furnishing passages for the metal-bearing solutions that have produced the ore deposits. They show great divergence in strike and dip, and no general rule governing their positions was determined.

ORE DEPOSITS.

The mineral deposits comprise replacement deposits in sedimentary rocks and veins in volcanic rocks. The replacement deposits are found principally in the limestone surrounding the central granitic mass, and the veins are confined to the volcanic rocks south of Beaver Canyon.

REPLACEMENT DEPOSITS IN SEDIMENTARY ROCKS.

The replacement deposits in sedimentary rocks may, in turn, be separated into those formed near the granite contact, containing calcium, iron, and magnesium silicates as gangue minerals and commonly designated contact deposits, and those formed as a replacement of limestone adjacent to fissures at some distance from the contact.

CONTACT DEPOSITS.

OCCURRENCE AND CHARACTER.

Contact deposits are probably the most numerous of any type in the range. Although they have yielded only small amounts of metal, the surface showings have been sufficient to encourage considerable prospecting. The limestone at and near the large intrusive bodies is commonly recrystallized to a white crystalline limestone and contains small amounts of the contact silicates. Garnet, vesuvianite, and tremolite are most abundant, but epidote, chlorite, and muscovite are present. At places along the contact the silicate minerals become abundant, and magnetite, hematite, and the sulphides of copper, lead, and zinc are present. Most of these deposits are irregular or "bunchy," and though bodies of good ore have been found, most of them are too small to be profitably worked. Small shipments have been made from the Oak Leaf property on the east side of the range, where the deposits grade from typical contact deposits to deposits resembling those of the replacement fissure type. Contact deposits have been prospected at numerous points along the east side of the granite body, and a little ore is reported to have been shipped from several claims.

MINES.

Bismuth mine.—Deposits that mineralogically are to be classed with the contact deposits occur at some distance from large bodies of intrusive rock. An example of this type is the "Bismuth" mine on the east side of the range, where a stratum of limestone about 6 feet thick has been almost completely replaced by contact minerals, mainly vesuvianite and green amphibole with some fluorite, calcite, and sulphides. The sulphides—pyrite, bismuthinite, molybdenite, and possibly others—are intergrown with the silicate minerals. The stratum is overlain and underlain by white siliceous limestones that have been recrystallized but have not developed abundant contact silicates. Granite is exposed a few hundred feet both northeast and southwest of the prospected area on the strike of the sedimentary beds. The replaced bed has been exposed along the strike by open cuts and shafts for several hundred feet and can be traced on the surface for a greater distance.

The writer has no reliable data as to the metal content of the ore. A hasty inspection of the dumps and shallow workings revealed no material that appeared to carry more than a small percentage of either bismuth or molybdenum.

Lincoln mine.—The Lincoln mine, about 5 miles northeast of Minersville, may also be classed with the contact deposits, though it has some characteristics of the replacement-fissure deposits. The sedimentary rocks in the vicinity are limestones, siliceous limestones, and quartzites of upper Carboniferous age, cut by granitic and monzonitic rocks and some more basic dikes. East and south of the mine the granitic stocks are of considerable size. The limestone has been crystallized, and near the contact of the intrusive rocks and to some extent along fissures silicate minerals, garnet, tremolite, etc., have been developed.

The deposit was not examined underground, but from surface relations it appears to be in limestone near the contact of a monzonite porphyry dike. In the limestone on the dump contact silicates are plentiful and are intimately associated with ore minerals—galena, pyrite, chalcopyrite, and sphalerite. Zinc is said to have been unimportant in the upper portion of the ore body, but sphalerite is reported to be plentiful in the lowest workings, a report which seems to be confirmed by the presence of rather abundant sphalerite in the material last thrown on the dump. The shaft is said to have reached a depth of about 300 feet when work was stopped by the inflow of water.

Observations were not sufficient to determine whether the ore minerals were deposited at the time of the intrusion of the dike or were the result of later solutions passing along a fissure previously occupied by the dike.

The conditions in the Lincoln (formerly Rollins) mine at the time of the earlier operations are reported by P. T. Farnsworth[1] as follows:

> The shaft of the Rollins mine was sunk at an incline of about 80° for 230 feet in limestone, following a chimney of lead ore, which formed quite a large deposit on the surface. The lead ore of shipping grade was followed within the dimensions of the shaft and at 200 feet entirely gave out, being replaced by zinc sulphide near the water level. No ore was found by drifting, which was done at a depth of 100 feet. The total output of lead did not aggregate a thousand tons.

[1] Personal communication, Mar. 2, 1915.

Nip and Tuck mine.—The Nip and Tuck mine is about 4 miles northeast of the Cave mine near the summit of the range. The rocks in the vicinity are mainly limestone and quartzite, which have been intruded by fine-grained granite porphyry. In general the porphyry has been intruded along the bedding planes but in numerous places has broken across the beds. There has been some movement later than the intrusion, and the planes of least resistance appear to have been very commonly along the contact between the intrusive and the sedimentary rocks, producing in many places a gouge with prominent slickensiding.

Mineralization is said to have been most extensive in blue limestone underlying granite porphyry. The ore is largely oxidized, consisting of hydrous iron oxide, carbonate, and probably also sulphate of lead, with associated gold and silver. The precious metals are rather high and are commonly the most valuable constituents of the ore. The presence of tremolite in some of the ore and the presence of that and other contact minerals in limestone associated with the porphyry at other points suggest that the deposits are to be classed with the contact type.

Hecla mine.—The Hecla mine is southwest of the Nip and Tuck and several hundred feet lower. It was not in operation at the time of visit and was examined only superficially. The ore deposits, like those of the Nip and Tuck mine, are closely associated with granite porphyry.

REPLACEMENT-FISSURE DEPOSITS.

BRADSHAW DISTRICT.

Cave mine.—The most important and largest replacement-fissure deposit yet developed in the range is the Cave mine on the eastern slope of the range, about 6 to 7 miles north of Minersville and about 10 miles southeast of Milford, at an elevation of about 7,000 feet.

The sedimentary rocks in the vicinity are the Carboniferous limestones. Some highly altered basic dikes outcrop near the mouth of the lower tunnel, and bodies of fine-grained granite porphyry and more basic rocks lie to the north and west.

The sedimentary rocks have been considerably faulted and fissured. There are numerous east-west and north-south fissures, both dipping steeply. Some nearly horizontal movement is shown in the lower tunnel and in a small cave north of the discovery cave. The main ore shoot appears to be associated with a north-south fissure, though observations were not sufficient to show that other fissures had not influenced the deposition of the ores. Where the limestone was particularly favorable to replacement, mineralization extended considerable distances from the fissure. The original ore minerals were doubtless sulphides, but oxidation has been rather complete to the depth of present developments.

The ores extracted have consisted principally of limonite and cerusite with associated gold and silver. The high percentage of iron has made it possible to market much ore that could not have been profitably extracted for its gold, silver, and lead contents alone.

The main ore shoot has been developed by an irregular incline about 300 feet deep (estimated), whose bottom is connected with the surface by a tunnel about 2,000 feet long. A higher tunnel connects with the workings about 140 feet below the outcrop. Prospect and development openings have been made in several directions from the main shoot, but few of them could be examined. The caves associated with the ore deposits appear to have resulted from a shrinkage of the deposit in oxidation and probably also from solution of the limestone along this relatively open channel.

Huntley[1] describes the conditions as follows:

> The ore occurs entirely on the bottoms of caves in limestone or dolomite. Five large caves and 15 smaller ones had been found. They are all connected by seams of ocher, or by holes which serve as runways for mountain rats. Beyond the caves already known there are doubtless others, as holes and other seams lead outward. The largest cave is 120 feet long, 30 feet wide, and 20 feet high, extreme dimensions. One of average size is not over 12 feet in extent. All have an extremely irregular outline. The roofs of some are covered with a thin coating of copper carbonate and silicate. There is usually a vacant space from 1 foot to 10 feet between the roof and the ore. On the ore is usually a mass from 1 foot to 3 feet thick of blocks of limestone which have fallen from the roof. The upper portions of the deposits are generally softer, more earthy, and less valuable than the lower, where the carbonate of lead occurs. In some places the fine ocher changes into a hard massive limonite, with cavities having botryoidal and stalactitic surfaces. In spots, pure granular or crystallized sulphur is found, though not frequently.

[1] Huntley, D. B., Precious metals: Tenth Census U. S., vol. 13, p. 474, 1885.

Minor deposits.—Several other deposits in the Bradshaw district have produced ores, but none were active at the time of visit.

ANTELOPE DISTRICT.

In the Antelope district, at the north end of the range on the west side, are deposits which are probably to be classed with the replacement-fissure type. The ores are in certain beds of the limestone, but at the surface fissures crossing the bedding were not observed associated with the deposits.

The ore consists for the most part of galena in a gangue of barite and calcite. Oxidized ores are present to a minor extent at the surface and some float containing copper carbonates in a barite gangue was seen. There has been some prospecting of the deposits by shallow inclines and by tunnel, but at the time of visit no operations were being carried on.

VEINS IN VOLCANIC ROCKS.

So far as known, the veins in the volcanic rocks are present only in the portion of the range south of Beaver Canyon commonly known as the "Jarloose" district.

The volcanic rocks have been cut by fissures that trend north to northeast, adjacent to which they have been silicified and pyritized. On weathering, these metamorphosed rocks alter to yellow to reddish brown, and, being more resistant, usually stand slightly above the general level. This rock when examined in the hand specimen is seen to contain small veinlets of quartz and crystals of pyrite, or, in the weathered rocks, cavities containing the alteration products of pyrite.

The portions containing the most iron are said to give the best pannings of gold. The silicified "ledges" are numerous, and some of them can be traced for several hundred feet. Material that was said to "pan well" was in small ledges and was apparently confined to small streaks in the ledges. One poorly defined vein, containing abundant calcite with some quartz and copper carbonate, was stated to have assayed high in gold and silver. Considerable prospecting has recently been reported.

ORIGIN OF THE ORES.

The origin of the contact deposits and of the closely allied replacement veins in the sedimentary rocks can be referred, with much assurance, to the intrusion of the granitic rocks. Evidence as to the origin of the veins in the volcanic rocks is meager, but comparison with those in the Tushar Range to which they are most closely allied suggests that they also are after-effects of igneous activity.

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TUSHAR RANGE.

By B. S. BUTLER.[1]

GEOGRAPHY.

The Tushar Mountains are in southern Utah in Beaver and Piute counties. Their northern extension is the Pavant Range, from which they are separated by a low divide. They are the highest mountains in southern Utah and their peaks, except for some in the Uinta Mountains, are the highest in the State. Mount Belknap, Mount Baldy, and Delano Peak all rise above 12,000 feet. The range trends generally north between Sevier Valley on the east and Beaver Valley and its northward extension on the west. The width of the range in the latitude of Marysvale is about 15 miles.

From the summits of Delano, Baldy, and Belknap peaks the mountain slopes away in all directions. The slope northward along the crest of the range to the Clear Creek Pass is relatively rapid, the crest line descending 5,000 feet in about 10 miles. Southward from the main summits the descent of the crest is less abrupt, maintaining a height of nearly 10,000 feet for about 20 miles and then descending to slightly over 7,000 feet in Fremont Pass. From the main crest long spurs separated by deep canyons descend laterally to the valleys on the east and west. The bottoms of both Sevier and Beaver valleys in the latitude of the highest peaks are about 6,000 feet above sea level, giving the higher peaks a maximum relief of about 6,000 feet and the crest of the range for many miles a relief of fully a mile. In Sevier Valley south of Marysvale the base of the range is bordered

[1] Based on a reconnaissance made by the writer in the fall of 1911.

by a gently sloping gravel terrace, in which Sevier River and the mountain streams have cut relatively narrow canyon-like valleys.

The high range receives a relatively heavy precipitation, which, falling as snow in winter, melts slowly and maintains the stream flow far into the summer. In some seasons snow remains in the range in protected places throughout the year.

The drainage is into Sevier River. That from the east side of the range flows directly to the river, and that from the west flows to Beaver Creek, which flows westward through the Mineral Range and joins the Sevier north of Milford. The streams coming into the Sevier Valley furnish water for the irrigation of numerous ranches, and Beaver River supplies several prosperous communities. The waters of the Beaver River are also utilized for the development of electric power, and other streams could be so utilized if necessary. The higher portions of the range (except the highest peaks which are above timber line and nearly devoid of vegetation) bear a rather abundant growth of timber suitable for building and mining. Generally, the camps of the Tushar Range are better supplied with water, timber, and farm products than most districts of the State.

PHYSIOGRAPHY.

Physiographically the Tushar Range, as noted by Dutton,[1] is a transitional between the basin ranges on the west and the high plateaus on the east, being broader and less tilted than the one and narrower and more tilted than the other. It consists of a long narrow block bounded on the east and west by great faults. Sevier Valley, to the east of the range, is a remarkable structural trough formed by the relative sinking of a narrow block between two great parallel faults.

However, though the main outline of the range is due to great structural breaks and dislocations, most of the details are the result of erosion, which has dissected the great tabular mass forming the range into spurs and canyons. Some of the east-west canyons, however, apparently owe their position to fault zones, though they do not follow them throughout their extent. The greater part of the erosion is due to ordinary agencies, but that in the higher parts of the range is partly due to glaciers, as is plainly shown by cirquelike valleys and morainal deposits.

In the vicinity of Marysvale gravel terraces that occupy the margins of the valleys high above the present levels of the streams were evidently formed before the main river canyon was cut to its present depth.

This canyon cuts through a mass of igneous rocks that Dutton [2] attributes to outbursts of volcanic material in the bottom of the valley:

> Twenty miles north of Circle Valley and just below the hamlet of Marysvale another considerable barrier lies across the valley of the Sevier. It consists of a mass of rhyolitic lavas, which broke out in the valley bottom in many eruptions and now remain as a chaos of tangled sheets stretching from wall to wall. The river has maintained a canyon through the mass right at the base of the spurs of the Tushar, whose front here is not mural but mountainous.

Dutton evidently did not examine this barrier closely and was not aware that it was made up in considerable part of granitic rock intrusive into the flows and tuffs. It is hardly conceivable that a large mass of fluid rock material could have been intruded into a small mass of lavas and tuffs after the valley had been formed in essentially its present form and solidified as a granitic rock. To the writer it seems more natural to assume that in the sinking of the block that forms the bottom of Sevier Valley some portions were depressed less than others and thus there were structural elevations and depressions—the valley south of Marysvale being such a depression and the barrier north of Marysvale being such an elevation—or that irregularities in the surface previous to faulting were retained in the sunken block. Dutton [3] notes that local uplifts transverse to the valley are associated with the obstruction south of Circle Valley. Such uplifts may well have occurred in connection with the obstruction near Marysvale, though no evidence of them was noted. Whatever the cause of the barrier the area behind it would naturally be a collecting ground for the sediments from the adjacent mountains till the river had cut through the barrier and furnished an outlet. The stream then began clearing the valley of the material. The terraces represent the portion still remaining.

[1] Dutton, C. E. Geology of the high plateaus of Utah, p. 173, U. S. Geog. and Geol. Survey Rocky Mountain Region, 1880.

[2] Idem, p. 213.

[3] Idem, p. 212.

GEOLOGY.

SEDIMENTARY ROCKS.

The exposed rocks of the range are largely igneous, the basement on which the extrusive rocks rest being exposed in relatively few places and over relatively small areas. Wherever exposed it is seen to be composed of sedimentary rocks—mainly limestones and quartzitic sandstones with some shaly sediments. Its largest exposure is along the east front of the range between Bullion and Tenmile canyons. Within the main canyons (Bullion, Little Cottonwood, and Tenmile) the sedimentary rocks outcrop for several miles.

The rocks are too poorly exposed and have been too greatly disturbed to make an accurate understanding of their stratigraphy possible without detailed mapping. In Little Cottonwood Canyon, where the exposures are best, a rough estimate of the thickness shows interbedded quartzite and limestone 500 to 600 feet thick, overlain by 300 to 400 feet of massive quartzite overlain in turn by a series of limestone and shaly beds whose thickness probably exceeds 1,000 feet, the whole overlain by quartzite, a few hundred feet of which is still preserved. In Tenmile Canyon there is a considerable thickness of sandstones and shales. The relations of the two were not determined.

The age of the sedimentary rocks of the Tushar Range is given as Jurassic by Dutton [1] on the basis of the presence of the fossil form *Pentacrinus asteriscus*. Fossils obtained by the writer from the upper limestone of Little Cottonwood Canyon were determined and ascribed to the Jurassic by J. B. Reeside, jr., as follows:

7890. No. 45. Loose fragments from upper limestone, Cottonwood Canyon: *Ostrea* cf. *O. strigilecula* White, *Pholadomya* cf. *P. kingii* Meek, and *Camptonectes stygius* White.

7891. No. 27. Cottonwood Canyon: *Camptonectes stygius* White, *Camptonectes?* sp., and *Pentacrinus* sp.

IGNEOUS ROCKS.

EXTRUSIVE ROCKS.

Areally the volcanic rocks are by far the most widespread. They vary in character from massive flows of porphyritic rock to extensive beds of fine stratified tuffs, locally known as shale, interstratified with beds of volcanic débris accumulated from the earlier flows by erosion between eruptions. According to Dutton [2] such volcanic sediments are present in large amounts in the southern part of the range and indicate that at the time of their accumulation the northern part of the range was the higher and furnished the material for the sediments deposited to the south.

In the northern part of the range the volcanic rocks may be roughly separated into a basal portion composed mainly of massive flows and breccias and an upper portion composed predominantly of tuffs and thin flows. The basal portion is well exposed in Bullion, Little Cottonwood, and Tenmile canyons and is present to a less extent farther north on the west side of the range.

In mineral composition the successive flows show slight differences in composition, but all belong to intermediate groups. Quartz phenocrysts are present in most of the rock, though in some places they are relatively scarce. Plagioclase (andesine) predominates over orthoclase in the phenocrysts. In the groundmass the relative abundance of the feldspars can not be determined. Both hornblende and biotite were abundant but have usually been partly or entirely altered to secondary minerals. From microscopic study the rocks are classed as dacite, though chemical investigation would doubtless show that some of them are quartz latite and some possibly might be classed as andesite.

Overlying the heavy flows and forming the higher parts of the range, especially to the north, where they extend well down toward the base, is a series of light-colored rhyolitic flows and tuffs, locally known as "shale." Similar rocks were seen in considerable abundance in the volcanic mass in Sevier Valley north of Marysvale. The composition of these rocks is not known, as they have not been analyzed chemically and are too fine grained to be determined microscopically. In large part they are distinctly rhyolitic and are doubtless either true rhyolites or quartz latites. Whether these rhyolitic rocks ever covered the entire range can not be stated positively. Their greater abundance toward the north, however, suggests that they were erupted from vents in the northern part of the range and that if they ever extended over the southern and southeastern portions, it was as a relatively thin

[1] Op. cit., p. 181.

[2] Op. cit., p. 178.

covering. The latest eruptive rocks in the range are basaltic flows, which cover an extensive area southeast of Beaver.

INTRUSIVE ROCKS.

Intrusive rocks as observed in the range are of relatively slight areal extent. Two considerable bodies were noted and numerous dikes are present in various parts of the district. It is possible and even probable that sills of porphyry are also present, but if so, they resemble the flow rocks so closely that detailed study will be necessary to prove their presence. The larger intrusive bodies are in the Antelope Range north of Marysvale and on the western flanks of Baldy and Belknap peaks, several miles north of Beaver. Neither body has been carefully outlined, but each is several square miles in extent. The one north of Beaver, shown on earlier maps as pre-Cambrian, occupies 30 to 40 square miles, and the one in the Antelope Range must occupy 8 to 10 square miles.

The main body of both intrusive masses is composed of rather abundant quartz with orthoclase and plagioclase in about equal amounts. The rock contains also considerable augite, biotite, and magnetite and in composition corresponds to quartz monzonite. Locally, the rocks are more acidic and pass into true granite. Some phases of the rocks that showed no free quartz may be classed as monzonite.

Dikes cut both the volcanic and the sedimentary rocks of the range. Most of them are rather fine grained, porphyritic, and range in composition from quartz monzonite porphyry to basic types containing abundant augite and biotite, with the general composition of camptonite. They closely resemble the porphyritic lavas, from which they are not readily distinguished, and without detailed work it is impossible to state how abundant they are. Prominent dikes of the monzonitic and dioritic composition are present near the Sevier Consolidated and Annie Laurie mines, and more basic dikes were noted in upper Tenmile Canyon and in the Deertrail mine.

RELATION OF THE INTRUSIVE TO THE FLOW ROCKS.

The relation of the large intrusive masses to the flow rocks is not everywhere obvious, but dike rocks extending from the main mass into the overlying volcanic rocks were noted, and these, together with the change in texture of the intrusive rock from granitic to distinctly porphyritic near the contact with the flow rocks, indicates that the intrusive rocks are later than the flows. Their present relations are believed to be due to the intrusion of the granitic rocks into the flows rather than to the burial of an old erosion surface beneath the lavas.

The flow rocks have been considerably altered near the intrusive contact, and the general outline of the granitic areas in the Antelope Range can be readily traced from a distance by the highly colored rocks at the contact. A similar alteration in the Indian Creek area is shown at the Red Buttes, north of the Rob Roy mine.

AGE OF THE IGNEOUS ROCKS.

Within the Tushar Range only Jurassic sediments and those of recent formation have been recognized, so that it is impossible to determine closely the age of the igneous rocks. The extrusive rocks flowed out on the eroded surface of the Jurassic sediments and are therefore post-Jurassic. From evidence in adjoining areas, however, Dutton has concluded that volcanism began in early Tertiary time and continued through a long period. The latest volcanic activity, the outpouring of basaltic lavas, was of very recent date and may have occurred only a few thousand years ago. It seems probable that the volcanic eruptions which built up the main range were active at intervals through the middle and possibly into late Tertiary time. The granitic rocks are later than the main body of the flows and their intrusion may have taken place as recently as late Tertiary.

STRUCTURE.

Faulting has been important in the creation of the present Tushar Range. According to Dutton a fault extends for miles along the eastern front of this range and its extensions and is paralleled by another fault (the Sevier fault) a few miles to the east. Sevier Valley is considered to have been formed by the subsidence of the block between these great faults.

The western face of the Tushar Range is in line with the extension of the Hurricane fault, which is prominent farther south and is considered by Lee [1] to form the western boundary of the range. Within the Tushar Range there

[1] Lee, W. T., Water resources of Beaver Valley, Utah: U. S. Geol. Survey Water-Supply Paper 217, p. 13, 1908.

has been considerable north-south faulting parallel to the great faults that outline the range. These minor faults are, as a rule, not readily recognized, on account of the similarity of the successive flows and the small amount of sedimentary rocks, but in places they are easily determined. Such a fault is well exposed near the Crystal mine, south of Cottonwood Canyon, where the volcanic rocks are thrown down against the quartzites, the fault being marked by a zone of fault breccia. The northward extension of this fault marks the boundary between the quartzite to the east and the volcanic rocks to the west. A similar relation is seen in the workings of the Bully Boy mine, in Bullion Canyon, where in places quartzite forms one wall of the ore vein and volcanic rocks the other, and strong slickensiding testifies to the movement that has taken place. Similar displacements doubtless occur within the volcanic rocks, but, as already stated, the similarity of the rocks renders recognition difficult without detailed geologic work.

East-west faulting seems to have been less important, both in determining the structure of the range and in connection with the ore deposits. Some fissuring, which was unaccompanied by important movement but which permitted the circulation of mineral-bearing solutions, may also have taken place.

The main faulting occurred later than the extrusion of the bulk of the flow rocks. Its exact geologic time is not readily fixed, and, in fact, the movement doubtless continued at intervals over a considerable period. Dutton,[1] from a study of the faults over a wide area, concluded that the main fault movement began in late Tertiary time and continued perhaps even to the present day. That movement along some of these faults is still in progress has been indicated by severe earthquakes in recent years.

HISTORY AND PRODUCTION.

By V. C. Heikes.

The area of the Tushar Range includes the Gold Mountain, Ohio, Mount Baldy, Newton, and Henry districts.

GOLD MOUNTAIN DISTRICT.

The Gold Mountain district, in Piute and Sevier counties, was organized April 24, 1889. Kimberly, which was the principal camp, is 15 miles southwest of Sevier on the Denver & Rio Grande Railroad. According to Lindgren,[2] the region was known to be mineral bearing from the earlier days, for it lies only a few miles northwest of Marysvale and Bullion Creek. The ores, however, did not prove amenable to the ordinary amalgamation process, and the primitive reduction works were complete failures. With the advent of the cyanide process, however, a method which permitted the successful working of the ores was devised.

In 1892 the Sevier Consolidated Gold Mining Co. completed a 10-stamp pan-amalgamation mill and produced 100 ounces of gold and 398 ounces of silver from 210 tons of ore.

In 1894 the gold shipments are said to have averaged $5,000 monthly. During 1895 two mills, the Butler and Sevier, were in operation. In 1899 the Annie Laurie Mining Co. built its present mill and worked continuously from January, 1901, till the end of 1908. In 1905 the Sevier Co. replaced its 10-stamp mill with a new mill using a different treatment that involved concentration as well as plate amalgamation and cyanidation. The district produced a rather steady but small quantity of gold between 1892 and 1897 and again between 1903 and 1907. Between 1910 and 1913 the Sevier and Annie Laurie produced several thousand dollars' worth of gold and silver bullion.

Statistics of production for the district prior to 1901 are not available, but estimates, based on considerable information, are submitted in the tabulation below. Since 1902 the statistics of production have been compiled from the records of the United States Geological Survey.

OHIO DISTRICT.

The Ohio mining district is 6 miles southwest of Marysvale on Sevier River in Piute County. The district was organized in February, 1868, and again in August, 1872. In the seventies Bullion and Webster cities were important camps. Bullion was once the county seat of Piute County and contained about 200 inhabitants and 40 to 50 dwellings. Wheeler,[3] in 1872, states that the principal claims were the Daniel Webster, with a shaft

[1] Dutton, C. E., Geology of the high plateaus of Utah, U. S. Geog. and Geol. Survey Rocky Mtn. Region, 1880.

[2] Lindgren, Waldemar, The Annie Laurie mine, Piute County, Utah: U. S. Geol. Survey Bull. 285, p. 87, 1906.

[3] U. S. Geog. Surveys W. 100th Mer. Prog. Rept. 1872, pp. 14-25, 1874.

Metals produced in Gold Mountain district, 1892–1917.

Year.	Ore (short tons).	Gold.		Silver.		Total value.
		Fine ounces.	Value.	Fine ounces.	Value.	
1892–1900	[a] 21, 500	7, 740. 00	$160, 000	51, 000	$33, 507	$193, 507
1901	[a] 50, 000	18, 007. 72	372, 253	48, 213	28, 928	401, 181
1902	78, 946	23, 306. 80	481, 794	69, 223	36, 688	518, 482
1903	63, 246	20, 335. 60	420, 374	67, 109	36, 239	456, 613
1904	59, 586	18, 427. 80	380, 936	56, 647	32, 430	413, 366
1905	65, 800	19, 283. 00	398, 615	55, 536	33, 544	432, 159
1906	73, 909	15, 854. 75	327, 747	52, 126	34, 924	362, 671
1907	53, 850	12, 289. 90	254, 055	37, 138	24, 511	278, 566
1908	13, 341	3, 075. 00	63, 566	9, 425	4, 995	68, 561
1909	49	21. 89	452	28	15	467
1910	6, 090	563. 51	11, 649	1, 358	733	12, 382
1911	3, 004	1, 051. 56	21, 738	1, 256	666	22, 404
1912	310	144. 43	2, 985	455	279	3, 264
1913	10, 874	2, 383. 47	49, 271	5, 371	3, 244	52, 515
1914	131	279. 54	5, 778	1, 510	835	6, 613
1915	115	448. 82	9, 278	2, 003	1, 016	10, 294
1916	87	213. 58	4, 415	923	607	5, 022
1917	74	133. 90	2, 768	908	748	3, 516
	500, 912	143, 561. 27	2, 967, 674	460, 228	273, 909	3, 241, 583

[a] Partly estimated.

65 feet deep and a tunnel 50 feet long. Other claims were the Homestead, Blue Cloud, Spring Town, Niagara, Morning Star, St. Lawrence, and Great Western. Gold-bearing sand was discovered in Pine Gulch Creek in the early part of 1868, and about $100 worth of gold was washed out at an expense of several thousand dollars. This led to the discovery of a gold quartz vein by Capt. Hess. Considerable quicksilver, caught in the sluice boxes, was at one time thought to be a survival of earlier operations but is now known to have been derived from local rocks. In 1872 a mill with two 400-pound stamps, run by a 12-horsepower engine, was built by the Piute Silver Mining Co. but proved a failure and was not worked.

Huntley [1] says:

The Ohio mining district is a few miles square and includes several precipitous ridges and deep gorges on the eastern face of the Mount Baldy Range, 90 miles south of Juab. It was organized in 1868 or 1869 and reorganized in August, 1872. There were 130 locations on the records, but not a quarter of that number are still owned. Marysvale, 6 miles from the mines, in the valley of the Sevier River, is the district post office and the settlement from which supplies are obtained.

The Copper Belt property was developed in 1882 through a shaft 300 feet deep. Ore was milled at a 10-stamp mill in Bullion Canyon, some distance from the mine, but the yield did not equal expectations.[2] In 1884 the principal properties were the Copper Belt, Mohawk, Belle of the Vale, Manhattan, Webster, Bully Boy, Giles, Filmore, Elsie, Sierra Nevada, Bucher, and Chattanooga. In 1898 the Wedge property was discovered and has been a considerable producer of high-grade gold ore.

Mines of the Ohio district.[3]

Mines.	Total length of openings.	Remarks.
	Feet.	
Copper Belt	280	Ore assays $200 gold and about 200 ounces silver; 20 tons shipped prior to June, 1880.
Webster and Homestead.	[a] 200	Ore assays $12 gold and $58 silver, average.
Great Western	[b] 150	Ore assays $20 to $150 per ton.
Morning Star group.	300	Ore high-grade mill; few tons shipped in census year sold at $120 per ton.
Beecher	500	Ore averages $25 per ton.

[a] Shafts; also crosscuts, etc. [b] Shaft.

The Denver & Rio Grande Railroad was completed to Marysvale in 1900, and although it stimulated production to some extent the

[1] Precious metals: Tenth Census U. S., vol. 13, p. 462, 1885.

[2] Director of Mint Rept. upon production of precious metals, 1882, p. 239, 1883.

[3] Op. cit., p. 462.

ores shipped from the Ohio district did not come up to expectations. The production of the Ohio and Mount Baldy districts between 1868 and 1903 can not be exactly stated but is said to have been, with milling ores included, between 8,000 and 10,000 tons. Only since 1904 have the reports of producers been available to complete the following table:

Metals produced in Ohio and Mount Baldy mining districts, 1904–1917.

Year.	Ore (short tons).	Gold.		Silver.		Copper.		Lead.		Total value.
		Fine ounces.	Value.	Fine ounces.	Value.	Pounds.	Value.	Pounds.	Value.	
1904	73	26.31	$544	2,140	$1,225	....	....	17,350	$759	$2,528
1905	49	15.00	310	1,400	845	....	....	12,560	590	1,745
1906	30	5.00	103	380	255	....	....	....	....	358
1907	136	34.00	703	4,407	2,909	13,454	$2,691	32,296	1,712	8,015
1908	20	5.79	120	414	220	205	27	2,927	123	490
1909	53	16.87	349	1,050	545	3,632	472	881	38	1,404
1910	157	531.36	10,984	7,432	4,013	12,127	1,540	....	....	16,537
1911	154	204.66	4,230	4,137	2,192	7,816	977	....	....	7,399
1912	[a]1,025	22.87	473	2,368	1,457	3,106	512	21,889	985	3,427
1913	[a]935	121.42	2,510	4,368	2,638	3,904	605	46,458	2,044	7,797
1914	1,326	101.96	2,108	10,166	5,622	3,635	483	119,832	4,673	12,886
1915	69	1,168.69	24,159	772	391	463	81	8,231	152	24,783
1916	239	221.41	4,577	6,265	4,123	5,622	1,383	49,983	3,449	13,532
1917	2,054	905.83	18,725	45,832	37,766	18,770	5,124	540,476	46,481	168,696
	6,320	3,381.17	69,895	91,131	64,201	72,734	13,895	847,883	61,006	208,997

[a] Ore yielded some concentrates at Bully Boy mill.

in limestone. The ore contains horn silver in which particles of gold are visible. Seven tons of the sorted ore had been shipped and averaged about $100 gold and $200 silver per ton.

The Lucky Boy claim on the side of this mountain contains small bunches of selenide of mercury in limestone.

Other promising prospects in the district are the Alma, Plata de Mina, Uncle Sam, Rothschild, Clyde, Crystal, and Monte del Rey.

MOUNT BALDY DISTRICT.

The Mount Baldy district, in Piute County, adjoins the Ohio district on the north and extends along the precipitous eastern face of the same mountain range for 8 miles. Huntley[1] describes it as follows:

It was organized September 18, 1878, and the records show 190 locations. * * * The Deer Trail mine is situated on a very steep mountain side, 1,500 feet above the Sevier River valley, 5 miles southwest of Marysvale. It was discovered in September, 1878, and was the first location in the district. It was worked steadily until July, 1880. * * * The property consists of the Deer Trail, Green-eyed Monster, and Cliff claims on the same vein; the Pi Ute and Red Pine claims on a parallel vein on the bluff 1,000 feet above; two 5-acre mill sites and a sawmill site. * * * It (the ore) assays about $8 gold, $150 silver, and 35 per cent lead. The second-class ore is a hard quartz, assaying about $2 gold and $48 silver, and is still on the dump. * * * The exact product can not be stated but was a few hundred tons. * * *

The Green-eyed Monster is the northern extension of the Deer Trail. In this claim the vein suddenly enlarges and the ore is of lower grade. * * * It is estimated that the entire mass would average from $20 to $25 per ton, one-third of the value being gold. * * *

The Pluto mine is on the mountain side above the Deer Trail. It was located in June, 1879. It is a 20-inch vein

[1] Precious metals: Tenth Census U. S., vol. 13, p. 463, 1885.

It is reported[2] that a carload of ore was shipped from the Crystal mine in 1880.

Several hundred tons of smelting ore is mentioned in the census report as having been shipped from the district prior to 1880. All the ore shipped was hauled many miles until the railroad was completed to Manti in 1890 and to Marysvale in 1900. Records on file with the United States Geological Survey show shipments made in 1878 and for some of the following years:

Metals produced in Mount Baldy district, 1878–1882.

Year.	Ore (tons).	Gold.		Silver.		Total value.
		Fine ounces.	Value.	Fine ounces.	Value.	
1878	31	48.24	$997	6,396	$7,355	$8,352
1879	220	189.58	3,919	20,078	22,487	26,406
1880[a]	100	24.70	511	1,110	1,276	1,787
1882	83	72.39	1,496	4,565	5,204	6,700

[a] Partly estimated.

The production of gold, silver, and copper since 1903 is included in the table for the Ohio and Mount Baldy districts. (See p. 544.)

[2] Gibbs, J. F., personal communication.

In addition to shipping ore the Green-eyed Monster of the Deertrail group produced about 6,000 tons of milling ore containing about $15 in gold and 10 ounces of silver per ton. This ore was treated at a mill in Bullion Canyon, but owing to the large quantity of "talc" it contained and the unsuitable milling facilities the extraction did not average much over 60 per cent. The tailings, some of which were subsequently treated, were to a large extent carried away by flood waters. This body of milling ore is reported to have contained appreciable quantities of mercury in some of the workings. Development has continued and a large body of ore is said to have been proved, for the treatment of which a milling plant was completed in 1918.

Adjoining the Deertrail on the west, and owned by the same interests, is an interesting property known as the Lucky Boy. Selenide of mercury is found here and was worked for quicksilver, at one time yielding as high as 60 per cent. The total production is estimated as 213 flasks, valued at $8,308.[1]

NEWTON DISTRICT.

The Newton mining district, in Beaver County, 55 miles east of Milford, on the Los Angeles & Salt Lake Railroad, was organized November 26, 1892. By July, 1893, a 10-stamp amalgamation mill was operating on ore taken from the Rob Roy claim. The first gold bullion, valued at $800, was shipped in August, 1893. During September of the same year the Cremona group of claims was operated by the Sheep Rock Co. It is reported [2] that between November, 1892, and September, 1893, the Rob Roy property produced from $7,000 to $9,000 worth of gold from ore treated in its amalgamation mill. The ore mined did not appear to be in place and was soon exhausted. Considerable development has since been done on the property in trying to find the ledge from which the rich ore came. No records of the production of the district until 1908 are available, since which time the statistics have been compiled by the United States Geological Survey. They are included in the table giving the output of Beaver County.

[1] McCaskey, H. D., Quicksilver: U. S. Geol. Survey Mineral Resources, 1911, p. 911, 1912.

[2] Personal interview with P. T. Farnsworth, Salt Lake City, March, 1913.

HENRY DISTRICT.

The Henry district, organized July 6, 1883, is in the southern part of Sevier County. Between 1902 and 1911 there were shipped from the district 1,598 tons of ore containing $8,583 in gold and 28,316 ounces of silver, valued in all at $24,289. Some iron flux was shipped to Salt Lake smelters from the Krotki iron claims, southeast of Sevier, in the Durkee (unorganized) district, which is considered to be part of the Henry district.

ORE DEPOSITS.

GENERAL FEATURES.

The ores of the Tushar Range show great diversity in metal content. Some are essentially gold-silver ores, and others contain copper, lead, and zinc in considerable amounts. In the Antelope district some ores are valuable chiefly for their iron. The Tushar Range also has the only important deposits of alunite yet discovered in the State, and it contains one of the two mines of the State that have produced quicksilver in commercial amounts. The deposits show too many gradations to be readily divided into classes, but for convenience in description they may be grouped as veins and replacement deposits. Placer deposits are of small importance.

VEINS.

The principal metals produced by the vein deposits are gold and silver, though they also produce some lead and copper and contain considerable quantities of zinc. The alunite veins, which are included in this class, may prove a source of aluminum as well as of potash.

Most of the veins strike generally north to northwest, but a few strike nearly west. Most of them dip steeply.

GOLD-SILVER VEINS.

The veins in which gold and silver are the chief valuable metals are confined almost exclusively to the volcanic rocks. Such veins are found at several localities in the range. The most important is that about Kimberly, though there has been production from veins of this class from the Newton district, from the recently discovered Fortuna district on the western side of the range, and from the "Horse Heaven" area between Bullion and Little Cottonwood canyons. Similar veins have been prospected to a slight extent in Tenmile Canyon.

The veins have apparently formed as fillings of open fissures and in many places have a rather indefinite banded structure. In some of them the contact with the wall rock is sharp and there is strong slickensiding, but in others the vein is "frozen" to the walls and the contact is much less definite.

Alteration of the wall rocks is irregular, though rather pronounced. Nowhere, so far as observed, has there been sufficient addition of metals to the wall rock to make ore. The common alteration is sericitization of the feldspars and change of the dark silicates to chlorite and some epidote. Silicification is pronounced in many places.

The typical gangue minerals of the veins are quartz and carbonate and at several places adularia in considerable abundance. Barite is also a constituent of the gold-silver veins—in some places being rather plentiful though nowhere as abundant as the carbonate. Fluorite was noted in the Wedge vein and is probably present in others.

The carbonate is apparently variable in composition. In the oxidized ores hydrous oxides of both iron and manganese have apparently resulted from the alteration of the carbonate. Specimens were collected from the dump of the Dalton mine in which the carbonate is rhodochrosite, but this is apparently exceptional. Much of the carbonate is apparently nearly pure calcite. The carbonate and barite are among the earliest minerals to form, though some barite has formed in vugs lined with quartz. In many places both carbonate and barite have been partly or wholly replaced by quartz and adularia, giving the quartz the peculiar lamellar structure characteristic of this type of vein, both here and in other districts.

In many of the veins sulphides are rather sparse, though present in much of the adjacent altered rock. According to Lindgren[1] the Annie Laurie vein contains pyrite and small amounts of argentite and native gold. Copper stains are present, but the original copper mineral was not noted. Quicksilver is also reported as occurring in the mine. In the veins between Bullion and Little Cottonwood canyons pyrite is usually plentiful and tetrahedrite occurs in many places in considerable amount.

The only apparently primary silver mineral recognized has silvery-white metallic luster. It could not be separated in sufficient quantity for analysis, but tellurium and selenium are both shown by qualitative tests of rich ore. Much of it is coated by a dark-gray material of dull luster, apparently an alteration product. The mineral contains free gold in minute fissures, and possibly gold is one of its essential constituents. Material free from native gold was not obtained to test for other gold. In specimens of rich ore from the upper levels of the Bully Boy mine all the free gold is closely associated with this mineral and is possibly an alteration product of it. In specimens of rich ore from the same mine cerargyrite (horn silver) forms thin films along fissures.

So far as observed the tetrahedrite carries but little silver. Material containing several per cent of this mineral is said to contain only small quantities of precious metals and is ore only when it contains sufficient copper to be valuable for that metal.

The effect of secondary concentration on the ore could not be determined satisfactorily during the writer's visit. There seems to be no doubt that some of the richest ore occurred very near the outcrop of the ore bodies, so that, so far as indicated by past experience, richer zones are not to be expected at greater depths. Some placer deposits have been worked near the mouth of Bullion Canyon, and others are reported along the west base of the range, indicating that some metal-bearing portions of the veins have been eroded. The fact that more extensive placers are not associated with the larger veins (namely those near Kimberly) is probably due to the fact that only a small portion of the veins has been eroded and to the fact that part of the erosion was accomplished by glaciers which did not concentrate the gold in workable placers. Experience has shown that with increasing depth the ores decrease in value. None of the deeper workings on the gold-silver veins could be examined, but it is currently reported that the ore of the lower levels of the Annie Laurie mine is of much poorer grade. In the Sevier mine sufficient depth has not been attained to indicate positively the effect of depth. The same appears to be true in other mines between Bullion and Little Cottonwood canyons, as richer

[1] Lindgren, Waldemar, The Annie Laurie mine, Piute County, Utah: U. S. Geol. Survey Bull. 285, p. 89, 1906.

ore was found near the surface in the Bully Boy and Webster, the Dalton, and other mines than has been found as greater depth has been attained.

LEAD-COPPER-ZINC VEINS.

The veins that contain lead, copper, and zinc minerals in considerable abundance contain also gold and silver and are very closely related to the gold-silver veins, into which they doubtless grade. The veins carrying base metals thus far developed are mainly confined to Bullion and Little Cottonwood canyons and like the gold-silver veins are for the most part associated with north-south fissures.

Most of the base-metal deposits are within or closely associated with sedimentary rocks, limestones, or quartzites and all are at relatively low levels, whereas many of the important gold-silver deposits are found at the higher elevations. As the sedimentary rocks are also confined to the basal portion of the range, it is not readily apparent whether the distinction is due to the sedimentary rocks or the difference in vertical position. Not improbably it is due to both.

The lead-copper-zinc veins, like the gold-silver veins, were in part formed in open fissures, and some of them have beautifully polished walls, as in parts of the Bully Boy mine; others, however, have also replaced the wall rocks for short distances from the fissures. The adjacent volcanic rocks have undergone alteration similar to that of the rock adjacent to the gold-silver veins. The feldspars have been replaced by sericite and carbonate, and the dark silicates have commonly altered to chloride. Pyrite is rather sparingly present.

The abundant gangue minerals are quartz and carbonate, and the less abundant are barite and fluorite. The carbonate is an iron-manganese-calcium carbonate which on alteration commonly yields abundant hydrous oxides of iron and manganese. Both the carbonate and the barite were among the earliest vein minerals and have been partly replaced by quartz.

The primary metallic minerals are pyrite, chalcopyrite, tetrahedrite, galena, and sphalerite. Of these the pyrite is the earliest. It occurs mostly in irregular grains but in places shows definite crystal outline. Under the microscope pyrite crystals from the Clyde mine show films of chalcopyrite filling microscopic fissures. In other grains the films have been considerably broadened by replacement of the pyrite, and the grains appear to have been shattered and cemented by the chalcopyrite. In many grains replacement has proceeded till only small cores of pyrite remain and in some even the core has disappeared. Not all the chalcopyrite has formed at the expense of pyrite, but some appears to have crystallized independently of other minerals. Chalcopyrite and tetrahedrite are apparently of the same age, in many places being intimately intergrown. The tetrahedrite, so far as observed, however, does not form at the expense of pyrite, as does a part of the chalcopyrite. Galena is also of the same age as the chalcopyrite and tetrahedrite. Intricate intergrowths of galena and tetrahedrite are present in some of the ore, and sphalerite is also apparently of the same age. The only secondary sulphides positively recognized as the result of descending solutions are those of copper (chalcocite and covellite), which have formed commonly from chalcopyrite and to a slight extent from tetrahedrite. There has been very little direct replacement of pyrite by either chalcocite or covellite, though portions of pyrite grains first replaced by chalcopyrite have later been altered to covellite. It is probable that zinc sulphide has also been replaced by copper sulphides, though no material showing this was present in the sections examined.

In material from the Clyde mine, grains of sphalerite contain lathlike bodies of double-refracting material, evidently wurtzite. Some grains are largely composed of such laths. The relations of the minerals in this material does not suggest secondary alteration, though wurtzite is believed to be most commonly formed as a secondary mineral.

In the upper levels of all the base-metal deposits the ores have been oxidized, but material suitable for a careful study of the oxidation products was not available. Probably the galena was largely altered to lead carbonate and perhaps to lead-antimony compounds, and the copper minerals to carbonates and possibly to more complex copper compounds.

In the quartz monzonite of the Antelope Range numerous veins are composed of fine-grained cherty quartz containing some sulphide and said to contain small amounts of gold and silver. In the Bradburn tunnel a vein of this character contains epidote, garnet,

and magnetite, in addition to sulphides, and on the dump of this tunnel were collected specimens of an aplitic rock, apparently a dike containing tourmaline, pyrite, and chalcopyrite. Though there has been considerable prospecting of the veins in the quartz monzonite of the Antelope area there has been no important production of ore.

VEINS OF IRON ORE.

Some shipments have been made from deposits of iron ore in the quartz litite body in the central part of the Antelope Range. The ore bodies occur in irregular fissures. The quartz litite in the vicinity has been highly altered, being converted to a cherty mass. This body of silicified rock has been more resistant to erosion than the surrounding rock and stands up as a hill several hundred feet high. The iron deposits are near the summit of the elevation and near the center of the area of altered quartz monzonite. The silicified area is irregular but probably exceeds a mile in length from north to south and is fully half a mile in width. The altered rock is composed essentially of quartz with small amounts of oxides of iron and possibly of manganese.

The ore consists of yellow and reddish earthy hydrous oxide of iron, with some brown and black hydrous oxides of manganese and iron, and some beautifully formed stalactitic masses of limonite. The ores, as they now exist, appear to have been formed by the alteration of other minerals. In general the deposit does not differ markedly in appearance from the gossans formed by the oxidation of sulphide bodies. No remnants of sulphide were observed in the ore body, nor was sulphide noted in the adjacent wall rock. Considerable iron oxides together with other oxides were evidently removed from the monzonite during the alteration and this may have collected in the fissures and formed the bodies of iron ore.

ALUNITE VEINS.

In the area between Bullion and Little Cottonwood canyons, and south of Little Cottonwood Canyon, north as far as Belnap, and in the area northeast and east of Marysvale there has been considerable development of alunite deposits during the last few years. (See fig. 59.) The nature of these deposits was first recognized in the fall of 1910, though the veins of pink spar had long been known to prospectors.

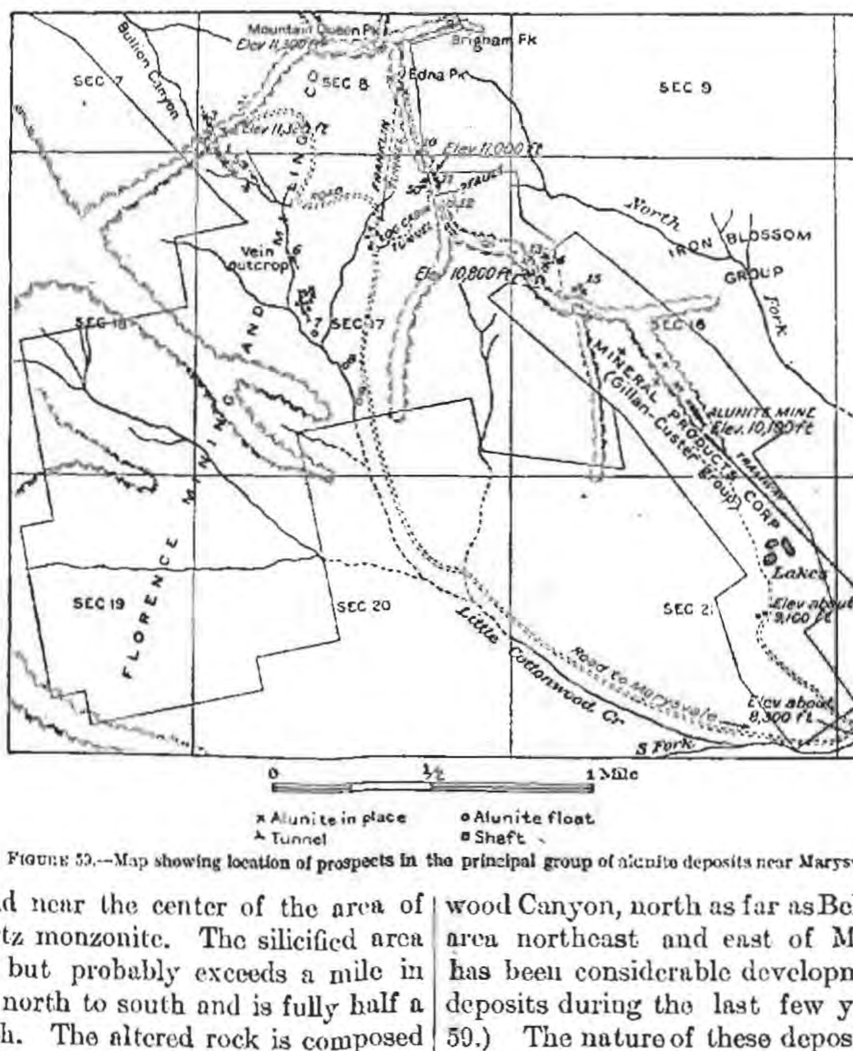

FIGURE 59.—Map showing location of prospects in the principal group of alunite deposits near Marysvale.

ALTERATION OF THE COUNTRY ROCK.

The deposits occur in large veins of almost pure alunite and as partial replacements of country rock.

The wall rock has been intensely altered for many feet from the veins, giving rise to the extensive masses of the silicified rock exemplified in the Edna "geyser." In the alteration of the rock the feldspar crystals have changed to a felted mass of needle-like crystals of alunite with some kaolinite. (See Pl. XXI, *B*, p. 182.) The dark silicates and the magnetite have also been entirely altered, only the phenocrysts of quartz remaining practically unattacked. The altered rock is made up essentially of quartz, alunite, pyrite, and of some kaolinite, all the constituents of the original lava except silica, alumina, potassium, and iron having been removed and sulphur having been added to the alumina and potassium and iron to form alunite and pyrite. At some places the potassium has been removed from the altered rock, which consists largely of cherty quartz; at other places there has been a notable addition of potash. Large bodies of such rock contain as high as 8 per cent of potash, while the silica content may be reduced to less than 20 per cent. The large bodies of alunitized rock near Deer Creek and those east of Sevier River are prevailingly of this replacement type, as contrasted with the veins of nearly pure alunite that occur in the higher parts of the Tushar Range southwest of Marysvale.

OCCURRENCE AND CHARACTER.

The alunite deposits that have been extensively mined occur as banded veins (see Pl. XX, *B*, p. 181) between rather definite walls, though, as already noted, alunite is an important constituent of the wall rock. It is apparent that the main veins are not replacements of the country rock, for where replacement has occurred in the wall rock of these veins the quartz phenocrysts are practically unaltered and the silica set free by the alteration of other minerals is not removed. The vein, on the other hand, is almost free from silica. In some portions of the vein the material is coarsely crystalline, the crystals having a tabular form and in places extending across a layer of the banding. Commonly the crystals tend to diverge from a center of tufts, this being more noticeable under the microscope than in the hand specimen. The rhombohedral faces of the crystals are not usually well developed, but in many places an open cavity between two bands shows well-developed rhombohedral faces, which, however, have commonly been somewhat etched by later solution. What in the hand specimen appear to be crystals are seen under the microscope to be composed of numerous smaller crystals diverging from a central axis, forming a very striking plumose structure. The difference in orientation of these component parts of the "crystal" group gives it a wavy extinction between crossed nicols.

The lines marking the separation of the bands forming the vein are seen under the microscope to consist of narrow bands of finely crystalline material of various orientations. The larger "crystals," however, cross these lines without change in orientation, suggesting that the fine material has been deposited in a fissure breaking across the crystals. Probably there was a slight change in conditions of deposition, after which some of the crystals continued their growth and others began to form from new centers.

In other parts of the vein the alunite is finer grained and locally lighter in color. In some places it is very dense and breaks with a conchoidal fracture; in others, where there has been some movement, it is schistose and shows numerous slickensided faces. Under the microscope the finely grained material is seen to be a granular mass of irregular crystals of alunite. Associated with these in the section examined is a mineral with lower index and having the general characters of kaolinite. Chemical analysis indicates that both kaolinite and some quartz are present as impurities in the alunite. Through this fine-grained material are scattered veinlets half an inch or more in thickness of more coarsely crystalline alunite. Loughlin[2] considers that the alunite in these veinlets has resulted from the recrystallization of the fine material which incloses them.

The deposits near Deer Creek and east of Sevier River are largely the result of replacement of the volcanic rocks, as contrasted with distinct veins. The more completely replaced rock is a dense fine-grained brittle material

[1] Butler, B. S., and Gale, H. S., Alunite—a newly discovered deposit near Marysvale, Utah: U. S. Geol. Survey Bull. 511, p. 20, 1912.

[2] Loughlin, G. F., Recent alunite developments near Marysvale and Beaver, Utah: U. S. Geol. Survey Bull. 620, p. 244, 1915.

breaking with shelly fracture and having somewhat the appearance of porcelain. Locally it is rather soft and chalky and grades from slightly altered lavas to rock composed largely of alunite. Large bodies of the alunite rock are found in the district, but up to the present time little potash has been produced from them.

The following description of the character of the deposit is taken from Loughlin's report.[1] Those desiring a more detailed description are recommended to that report and an earlier one by the writer and H. S. Gale.[2]

All the deposits thus far found are doubtless veins cutting porphyry (altered dacite), though in only a few exposures have their true thicknesses and exact trends been determined. The alignment of prospect pits and trenches and the distribution of float, however, indicate for the most part trends of N. 20°-40° W., though at a few openings the trend is nearly due north. The dips of the different veins are for the most part 50°-70° W., but vertical dips have been noted at a few places and a steep easterly dip was recorded at one obscure exposure. None of the veins have been opened continuously along their strike, but the alignment of openings indicates probable lengths of 500 to 800 feet for continuous veins and of 1,500 to 5,000 feet for vein zones. The widths of the veins or vein zones are considerable, but the prospect trenches on all but the Custer vein did not, as a rule, afford a satisfactory estimate of the width or thickness. The Custer vein contains an average thickness of about 10 feet of high-grade alunite, on each side of which smaller veins or bands of alunite alternate with similar thicknesses of quartz or highly silicified porphyry.

The best exposure in the western zone is on the L. & N. No. 4 claim and shows an exposed thickness of 26 feet, of which 20½ feet is high-grade alunite and 5½ feet quartz. Other openings show thicknesses of 8 to 20 feet. The veins are distinctly banded, bands of nearly pure alunite alternating with bands of quartz. The alunite portions themselves are for the most part banded by parallel to concentric markings similar to those in travertine, or "onyx marble," and characteristic of open fissure fillings, but have also been found in some degree by replacement. The general distribution of the veins is indicated on the surface by elongate to irregular areas of silicification, many of which appear to have determined the positions of ridges and prominent peaks through their superior resistance to erosion.

Three varieties of alunite have been noted in the veins—coarsely crystalline, fine grained to dense, and laminated. The coarsely crystalline variety is by far the most common. It is pink to reddish and forms large masses of columnar to platy crystals as well as small veinlets that cut the other two varieties. It is practically pure but contains minute quantities of pyrite or limonite and silica (chalcedony and opal). It is most readily recognized in the field by these properties, together with its high specific gravity (about 2.82), which is distinctly higher than that of calcite (2.71), the only mineral in the region that is likely to resemble it in crystalline form.

The fine-grained variety is pink to white and resembles porcelain where hard and chalk where softened by weathering. Under the microscope some specimens are seen to consist almost entirely of minute crystals of alunite with only an apparently negligible amount of pyrite, silica, and kaolin; but in other specimens these impurities are more conspicuous. The fine-grained variety may resemble kaolin, or miner's "talc," especially if enough kaolin is present to yield its characteristic odor; but the fine-grained alunite, like the coarse-grained variety, may be recognized by its high specific gravity.

The laminated or shaly variety differs from the fine-grained variety only in its structure, which is evidently due to shearing along the plane of the vein. Such a structure could have been developed in either of the other varieties.

CHEMICAL COMPOSITION.

The following analyses of Marysvale alunite, which are all at present available, show the character of the coarsely crystalline and dense white varieties:

Analyses of alunite from Marysvale region, Utah.

Crude alunite from Custer group.[a]

	1	2	3
Alumina (Al_2O_3)	37.18	34.0	37.0
Ferric oxide (Fe_2O_3)	Trace.	Trace.	....
Sulphuric anhydride (SO_3)	38.34	36.54	38.6
Phosphoric anhydride (P_2O_5)	.58	.50	....
Potash (K_2O)	10.46	9.71	11.4
Soda (Na_2O)	.33	.56	....
Water above 105° C. (H_2O+)	12.90	13.08	13.0
Water below 105° C. (H_2O-)	.09	.11	....
Silica (SiO_2)	.22	5.28	....
	100.10	100.18	100.0

[a] Copied from U. S. Geol. Survey Bull. 511, p. 8, 1912.

1. Selected specimen of a clear pink, subtransparent, coarsely granular crystalline alunite. Supposedly best material. W. T. Schaller, analyst.
2. Selected specimen of a light-pink, very finely granular rock, of almost porcelain-like conchoidal fracture and no distinct structure. W. T. Schaller, analyst.
3. Theoretical composition according to Dana, Text-book of mineralogy, 1900 edition, p. 537.

Coarsely crystalline alunite from Florence Mining & Milling Co.'s claims.

	4	5
Loss on ignition	42.8	42.1
Insoluble residue (alumina with perhaps a little silica)	39.3	37.6
Potassium sulphate (K_2SO_4)	16.8	18.5
Equivalent potash (K_2O)	9.1	10.0

4. 1,000-pound sample from Sunshine Fraction claim.
5. 1,000-pound sample from North Fork claim.

[1] Loughlin, G. F., op. cit., p. 241.
[2] Butler, B. S., and Gale, H. S., Alunite, a newly discovered deposit near Marysvale, Utah: U. S. Geol. Survey Bull. 511, p. 7, 1912.

Calcined alunite.

[Said to represent the average of the coarsely crystalline alunite used in analyses 4 and 5. Determined by fusion with sodium carbonate.]

	4a	5a
Silica (SiO_2)	0.03	0.72
Alumina (Al_2O_3)	61.1	61.1
Ferric oxide (Fe_2O_3)	1.6	1.1
Sulphuric anhydride (SO_3)	19.0	18.1
Potassa (K_2O)	17.2	18.6
Lime (CaO)	None.	None.
Magnesia (MgO)	.29	.31
	99.22	99.93

[The same material determined by leaching.]

	4b	5b
Insoluble residue	61.8	62.2
Potassium sulphate (K_2SO_4)	32.6	32.0
Aluminum sulphate ($Al_2(SO_4)_3$)	4.4	5.0
	98.8	99.2

4 and 5, 4a and 5a, 4b and 5b. Made by Solvay Process Co. for Florence Mining & Milling Co.

The following description of the occurrence of alunite at Sheep Rock is abstracted from the paper by Mr. Loughlin:[1]

SHEEP ROCK DEPOSIT.

The Sheep Rock deposit is a quartz-alunite rock of too low grade to be of immediate commercial importance as a source of alunite but of considerable scientific interest.

Sheep Rock is in the Newton mining district, at the west base of the Tushar Mountains, about 10 miles northeast of Beaver. (See fig. 60.) It is a bare-topped nearly circular ledge about 900 feet in diameter, with a gently rounded summit of nearly white quartz-alunite rock, in part weathered into clusters of rounded residual boulders, which when seen from a distance bear a striking resemblance to a flock of sheep.

The relations of the deposit to the andesitic country rock are very obscure. Its west, south, and north sides are covered with talus and brush and pass beneath the alluvium of the valley; and the saddle connecting it with the andesite foothills is covered with float.

[1] Loughlin, G. F., op. cit., pp. 258-264.

The float, however, shows that the two rocks merge within a short space, and that the Sheep Rock deposit was formed by the replacement of andesite. No definite connection with neighboring metalliferous quartz veins is apparent on the surface, and none has been made in the underground workings of the mine.

The material of the deposit as a whole is of uniform character, light-gray to pinkish color, and very fine grained, banded texture, which, however, includes brecciated and concretionary phases and rock in which the porphyritic texture of the andesite is preserved. The alunite content also shows variations ranging from 10 per cent or less up to 60 per cent, but as a whole appears to be rather uniform and to average about 30 per cent, equivalent to 3.5 per cent of potash (K_2O).

The three following partial analyses of the quartz-alunite rock, two of average samples and one the high-grade variety, were made by R. K. Bailey, of the United States Geological Survey:

Analyses of quartz-alunite rock from Sheep Rock deposit.

	1	2	3
Silica (SiO_2)	60.83	70.78	30.12
Sulphate radicle (SO_3)	13.83	10.56	26.53
Potash (K_2O)	3.89	2.90	6.87

1. Average sample at summit of Sheep Rock.
2. Average sample around stake No. 2 (fig. 60).
3. High-grade sample, north slope of Sheep Rock.

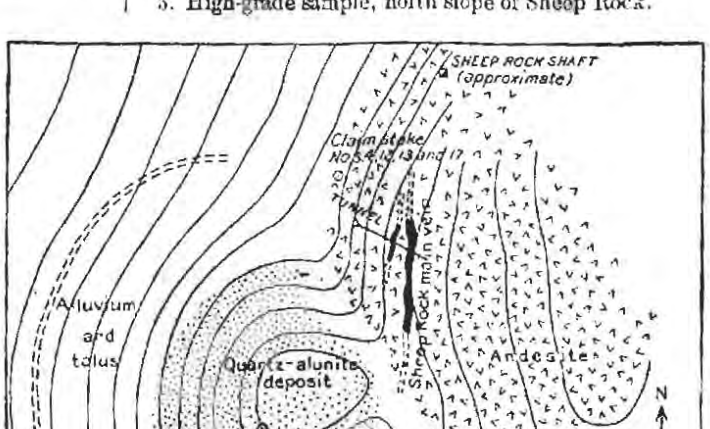

FIGURE 60.—Geologic sketch map showing relation of Sheep Rock quartz-alunite deposit to country rock and metalliferous veins.

In analysis 1 the ratio of the sulphate radicle to potash is almost exactly that of pure potash alunite. Calculation from these data gives over 13 per cent of alumina and 35.6 per cent of alunite. In analysis 2 the excess of 0.6 per cent of the sulphate radicle over the ratio between the sulphate radicle and potash for alunite is 0.6 per cent, a small excess which may have been present in the soda alunite molecule. The calculated percentage of alumina is only 9.5 per cent and of alunite 25.7 per cent. In analysis 3 the excess of the sulphate radicle is 3.2 per cent, which also may have been present in soda alunite. The calculated percentage of alumina in No. 3 is 22.3 per cent and that of alunite 60.3 per cent.

Since the examination by Mr. Loughlin alunite deposits have been reported from east of the Deertrail mine, north of Marysvale, and in the Antelope Range.

REPLACEMENT DEPOSITS.

Replacement deposits comprise those formed chiefly by replacement of rock adjacent to fissures as contrasted with the vein deposits, which were formed chiefly as a filling of open fissures. There are gradations between these classes, as exemplified in the Bully Boy and Webster mines, but most deposits distinctly belong to one or the other.

The only distinctive replacement deposits of known importance are the Deertrail lead-silver-gold deposit and the Lucky Boy quicksilver deposit.

DEERTRAIL MINE.

In the vicinity of the Deertrail mine the rocks are mainly the Jurassic quartzites overlain by 500 to 600 feet of limestone containing beds of shaly and quartzitic material. Within the workings of the Deertrail mine several small dikes of a highly altered lamprophyric rock carry abundant remnants of diopside and biotite.

Considerable faulting has occurred in the vicinity of the mine. The exact position of the great north-south fault that determined the front of the range is not known, but it can not be far to the east. In the gulch north of the mine the limestone and quartzites on the south abut against red shales and sandstones to the north along a fault striking west of north. East-west faulting has apparently shattered the rocks in the gulch. In the lower tunnel of the mine a north-south fault of unknown throw is exposed. There has also been some movement along some east-west fissures.

The general dip of the formations is 10°-15° W. In the Deertrail workings the attitude of the beds varies considerably from place to place on account of local disturbances. The ore is a blanket deposit that has replaced the limestone immediately above the quartzite and probably to some extent the quartzite itself. The replacement appears to be associated with east-west fissures. At several points the principal replacement has taken place at two horizons separated by 20 to 25 feet of relatively unaltered rock.

The character of the ore varies considerably. The most abundant gangue is a white micaceous aggregate composed largely of sericitic muscovite, in most places friable and capable of being readily crushed in the hand. Where the limestone has not been so fully replaced, however, the aggregate is rather compact. A partial analysis by W. T. Schaller gives the following result:

Analysis of sericitic muscovite gangue.

SiO_2	46.60
Al_2O_3	38.56
MgO	.86
CaO	None.
K_2O	8.40
Na_2O	.33
H_2O	5.02
	99.77

This analysis corresponds to about 75 per cent of muscovite containing a small amount of the paragonite molecule and about 25 per cent of a mineral approaching kaolinite in composition. In the southern portion of the property especially there is considerable coarse crystalline vein quartz. In panning the sericitic material it is seen to contain considerable zircon in rounded crystals and numerous black crystals of titanium oxide, probably octahedrite. Galena and pyrite and a small amount of copper sulphide were apparently the principal primary sulphides. The sulphides are largely oxidized and but little primary sulphide was seen (1912). That observed was in the margin of the deposit where, with a relatively small amount of sericitic muscovite, it replaced recrystallized limestone. The sulphides were altered to oxides, carbonates, and sulphates. D. B. Huntley[1] says: "The ore is a soft, friable,

[1] Tenth Census U. S., vol. 13, p. 463, 1885.

greenish-yellow ocher, containing the products from the oxidation of lead, iron, and copper sulphides. It assays about $8 gold, $150 silver, and 35 per cent lead."

According to a statement by G. T. Henry, the ores shipped from the mine amounted to about 350 tons, averaging about 1 ounce gold and nearly 100 ounces silver per ton and about 50 per cent lead. The lead was probably largely in the form of the carbonate and sulphate, though on the old dump specimens of plumbojarosite were collected, and Huntley's description suggests that it may have been an important ore mineral. Jarosite in considerable amount is also associated with the "talcose" ores. Hydrous oxide of iron and some manganese are present in all parts of the mine. Mr. Henry states that the sericitic ore contained small amounts of quicksilver.

Sufficiently rich material to determine in what form the gold and silver occur was not obtained. Panning of the sericitic ore did not yield colors of free gold. Mr. Henry states that in the early eighties between 6,000 and 7,000 tons of ore from the Green-eyed Monster (one of the claims of the group) was milled. The general average assay value was about $15 gold and 10 to 12 ounces silver per ton, but the sericitic character of the ore prevented the recovery of much more than 60 per cent of the assay content. It seems probable that the gold, in part at least, is finely divided free gold.

LUCKY BOY PROSPECT.

The quicksilver deposit of the Lucky Boy mine has been described by H. D. McCaskey [1] as follows:

The Lucky Boy quicksilver prospect was briefly described as follows by J. E. Clayton, president of the Salt Lake Mining Institute, in a letter to G. J. Brush, of the Sheffield Scientific School, dated October 6, 1884: [2]

> The mine is situated about 5 miles southwest of Marysvale, 200 miles south of Salt Lake City. It is on the east face of a mountain slope and near a profound fault extending north and south. To the east are eruptive rocks, including porphyry and trachyte. Underlying the ore beds to the west is quartzite of unknown thickness, over this about 400 feet of gray limestone, and in contact between these the Deertrail vein is situated, carrying gold, silver, lead, and a little copper. In the upper portions of the limestone the selenide of mercury is found in a bed of shaly limestone 15 to 20 feet thick. The vein has been traced north and south about 100 feet along the outcrop and dips into the mountain at an angle of about 15° below the horizon. The ore occurs in masses intermixed with the shaly limestone, crystals being very rare. The accompanying minerals are barite, oxide of manganese, quartz, and calcite. The ore bed is overlain by a yellowish sandy lime shale carrying sub-Carboniferous fossils.

The locality was visited by the writer in 1910. * * * The workings of the Lucky Boy mine just north of Cottonwood Canyon form a bowl-shaped open cut about 100 feet in diameter and 60 feet deep, a drift to the west about 80 feet into the mountain following the gently dipping bedding planes, a tortuous winze from the face of the drift turning back and coming out on the mountain side about 50 feet below the open cut, and a shaft at the bottom of the open cut, now filled with broken rock, reported to have been sunk about 40 feet on a north-south narrow nearly vertical vein carrying barite and some cinnabar. The cinnabar ore, it seems, was of low grade, and the commercial ore was mainly of onofrite and to a smaller degree of tiemannite, the sulphoselenide and the selenide of mercury, which were found in a deposit from 2 to 8 inches thick, following the bedding planes and impregnating the impure dark-gray limestone. Tiemannite was reported also from the barite vein, and the fissure here may have been the channel for the ore solutions. The intersection of this fissure with the bedding vein would be about where the open cut now is, and indeed much of the original deposit has probably been eroded away. The deposit was evidently superficial, for the life of the operations was short, the total output small, and it is now difficult to find even samples of ore in the workings. The occurrence is of especial interest as being the only deposit of the selenides of mercury in the country ever worked on a commercial scale, however small. The reduction was by two retorts operated in Cottonwood Canyon to the south of the mine. In the Deertrail gold mine, several hundred feet vertically below the Lucky Boy, and along the gently westward-dipping bedding planes at the quartzite and limestone boundary, cinnabar with pyrite was reported in a small lens. The deposition of quicksilver minerals in both properties may have been due to solutions arising through the same vertical north-south fissures thought to extend parallel to the great Sevier

[1] McCaskey, H. D., U. S. Geol. Survey Mineral Resources, 1911, pt. 1, p. 914, 1912.

[2] Penfield, S. L., Crystallized tiemannite and metacinnabarite: Am. Jour. Sci., 3d ser., vol. 29, p. 454, 1885.

fault, and may have been localized by transverse fissures similar to those known elsewhere in the district.

McCaskey[1] estimates the production of mercury from the mine as 213 flasks, valued at $8,308.

RELATIONS OF THE DIFFERENT DEPOSITS.

No facts have been observed that indicate more than one period of mineralization in the region, and certain resemblances between the several types of deposit suggest that they had a common origin. The gradation from veins in which lead, copper, and zinc are important constituents to those in which gold and silver are of chief importance leaves no doubt of the close relation and common origin of these two types of deposit.

The relations of the replacement deposits, as the Deertrail and Lucky Boy, are not so clearly indicated. These two deposits apparently are related in origin, for mercury, which is the principal metal of the Lucky Boy, is also present in the Deertrail. The Deertrail ore, like that of most of the veins, runs high in silver and gold as compared with base metals; much of it, indeed, is valuable solely for its precious metals. In the Lucky Boy mine the mercury is present as the selenide and sulphoselenide, and the gold ores contain both selenium and tellurium. The presence of the relatively rare element selenium in both types of deposit suggests a close relationship, as does also the presence of mercury in both.

The alunite veins differ markedly from the others but are still believed to be genetically related. The striking difference is in the absence of metallic sulphides in the alunite veins. Pyrite is present in the altered wall rock, but this has evidently been formed from iron already present, and no other metal except aluminum has been added. The resemblances are the presence of sulphates in both the alunite veins and in the metal deposits (in the latter in the form of barite). Perhaps the most striking resemblance is in the presence of potassium-aluminum minerals in all the deposits—in the Deertrail ore in large amount as muscovite, in the gold-silver veins as adularia (locally rather abundant), and in the alunite veins as hydrous potassium-aluminum sulphate.

[1] Op. cit., p. 914.

CONDITIONS OF DEPOSITION.

The composition of the veins and the general relations indicate that they are related in origin, but the wide difference in their minerals suggests that they must have formed under different conditions. That different minerals were deposited at slightly different times during the period of mineralization is indicated by the replacement of carbonates and barite by quartz and adularia. That they were deposited under different conditions is amply shown by the presence of magnetite and garnet, minerals generally recognized as forming under conditions of considerable heat and pressure, in some veins in the intrusive rock of the Antelope Range, while in other deposits are mercury and selenium minerals, adularia and alunite, which are regarded as forming under conditions of relatively low temperature and pressure.

These facts might be explained by the following order of events: (1) Successive beds of lava and tuff were ejected, with intervening periods of quiescence, during which the lavas lost most of their heat; (2) monzonitic masses were intruded with dikes extending into the lavas and more or less fissuring of the intruded rock; (3) the outer portions of these intrusive masses crystallized and in the readjustment due to cooling and possibly to other forces both the recently intruded rock and the overlying flows were further fissured; (4) along these fissures rose heated solutions, which within the intrusive mass were highly heated, and deposited minerals characteristic of this condition, but which as they passed into the cooler overlying rocks were subjected to reduced temperature and pressure, and this condition was recorded in the character of the deposits. The solutions seemingly underwent a progressive change in composition, depositing first abundant carbonates, later quartz and adularia, and finally sulphates.

The fact that the base metals occur most abundantly in close association with sedimentary rocks suggests that the sedimentary rocks may have precipitated the metals from the solutions. It is also noteworthy that the largest deposits, both of the quartz-adularia gold-silver and of the alunite, are at considerably higher elevations than the main deposits of base metals and are therefore considerably nearer the original surface, which may have been an important factor in determining the difference in character.

SOURCE OF MINERALIZING SOLUTIONS.

The origin of the solutions that formed the deposits can not be positively determined, but the most likely source seems to be the water given off by the crystallization of the magma that formed the intrusive body which underlies the lavas.

In this district, as in others where similar deposits have been studied, it is apparent that potassium and aluminum minerals were more abundantly deposited in the later stages of mineralization—either the solutions became richer in potassium and aluminum or the conditions for deposition of these elements became more favorable. The relative physical conditions under which the quartz-adularia veins and the alunite were deposited are not perfectly clear, but it seems highly probable that the alunite veins were deposited at lower temperature and pressure than the quartz-adularia veins, and that they represent a later stage, when the composition of the solutions had undergone a change. The relative rarity of alunite deposits may be due to the fact that they form near the surface and consequently have only in a few places been preserved. It is evident that when the alunite was formed the solutions were rich in sulphate, and if it was deposited later than the carbonate and quartz-adularia veins, as seems probable, it is to be expected that in places it will be found superimposed on the quartz-adularia, as the quartz-adularia is superimposed on the earlier carbonate veins.

The source of the potassium and aluminum has not been positively determined. In general, however, the potash contained in alunite is thought to have been derived from the alteration of the feldspar of the rock in which the deposits occur. In part, such an origin can be confidently stated for the alunite of the Marysvale deposit, but that it holds true for the main vein is not evident.

The characteristic alteration of the wall rock of veins of this type consists in a progressive leaching of the elements, potassium and aluminum being the latest, except silica, to be removed, but in some places these also have been leached out. In the wall rock of the alunite vein near Marysvale, however, the alunite appears to be sufficiently abundant to account for a large part of the potassium of the original rock, and therefore the rock immediately adjacent to the vein can not be considered as furnishing all the potassium for the vein by lateral secretion. In some of the other veins, however, practically all constituents except silica and iron have been removed and have not been deposited near by. This permits the interpretation that a part at least of the potassium and aluminum content of the vein may have been derived from the wall rock at greater depth where conditions were favorable for solution, the enriched solutions, rising into cooler zones, having redeposited these elements. If this is true one might expect that if the vein could be traced to the original surface the alunite deposits would gradually merge into those carrying other salts that were precipitated at still lower temperatures—if, indeed, alunite did not extend to the surface while more soluble salts were carried out on the surface in solution—and that on the other hand with increasing depth a zone would be reached that was not favorable to the deposition of alunite.

That the potassium and aluminum in the veins of this district were introduced by the solutions and were not derived directly from the wall rock is further indicated by the high potassium and aluminum content (as muscovite) of the Deertrail ores; these occur in quartzite and limestone, which do not contain notable amounts of potassium or aluminum, and consequently both of these elements must have been introduced. There seems no reasonable doubt that the mineral content of the veins, for the most part at least, was introduced by deep-seated solutions.

In this respect the evidence in the Marysvale region agrees with that in other districts of the West where similar Tertiary veins occur. Lindgren[1] has called attention to the similarity of the deposits in the northern part of the range to those of De Lamar, Idaho, and further similarities are shown by the sericitic ores of the Deertrail mine, which seem to resemble closely some of the "talcose" ores of the Idaho deposits that carry as high as 12.91 per cent[2] of potassa (K_2O). Lindgren concludes[3] that the main content of the Idaho

[1] Lindgren, Waldemar, The Annie Laurie mine, Piute County, Utah: U. S. Geol. Survey Bull. 285, p. 90, 1906.

[2] Lindgren, Waldemar, The gold and silver veins of Silver City, De Lamar, and other mining districts in Idaho: U. S. Geol. Survey Twentieth Ann. Rept., pt. 3, p. 171, 1900.

[3] Idem, p. 166.

veins was brought up from depth by thermal waters, and that the removal of alumina from the wall rock indicates the presence of sulphuric acid in the waters, though sulphates do not seem to have been deposited, or if deposited have not been preserved. Spurr [1] has concluded that the veins in the Tonopah district, Nev., which contain notable amounts of potassa in the form of adularia and in many respects resemble the adularia veins in the Marysvale district, derived their mineral content from heated waters given off by crystallizing magmas.

Schrader [2] has described similar deposits in the Black Mountains, Mohave County, Ariz., containing notable amounts of potassa in the form of adularia, and attributes their origin to hot waters ascending through the lavas at the close of igneous activity.

Schrader [3] has also described very similar deposits in the Jarbidge district, Elko County, Nev., which contain as high as 11.84 per cent of potassa (K_2O) in the form of adularia. He concludes that the veins were formed by ascending thermal solutions rich in silica, aluminum, and potassium.

Similar veins in New Mexico have been attributed by Lindgren, Graton, and Gordon [4] to ascending thermal waters, and a similar origin has been stated by Umpleby [5] for veins carrying some adularia in the Republic district, Wash. The writer believes that the deposits in the Gold Springs and State Line districts, Utah, and in the adjacent Fay district, Nev., are to be attributed to a similar origin.

Opinion appears to be uniform, therefore, that the veins carrying adularia were deposited by ascending thermal waters rich in silica, alumina, and potassa. Nowhere, however, outside of the Marysvale district have important alunite deposits associated with the adularia veins been recognized.

Of the alunite deposits of which detailed descriptions are available the one that shows the closest relation to the type under discussion is that at Goldfield, Nev., where alunite occurs as an important primary gangue mineral of gold deposits.

Ransome [6] considers the alunite at Goldfield to have been formed by solutions of deep-seated origin charged with hydrogen sulphide that rose to the surface of the earth, where the hydrogen sulphide was oxidized to sulphuric acid. The acidic solution percolated downward and in a heated zone reacted with potassium-aluminum silicates to form alunite.

Larsen [7] has described the occurrence of alunite in the San Cristobal quadrangle, Colo., and also of the allied mineral hinsdalite ($2PbO.3Al_2O_3.2SO_3.P_2O_3.6H_2O$), which is associated with metal sulphides. Larsen says: "The field relations point strongly to deep-seated hot sulphuric-acid solutions without the aid of surface agents." Larsen, however, suggests the possibility of the mineral having formed in a manner similar to that described by Ransome for Goldfield.

The alunite deposits in the Marysvale district are believed to have formed near the surface, and it is possible that the sulphate may have been formed by the oxidation of hydrogen sulphide, but this must have occurred by the mingling of solutions at considerable depth.

For further discussion see page 184.

GOLD MOUNTAIN DISTRICT.

By B. S. Butler.

The Gold Mountain district has been by far the most productive in the range. The output, which has been entirely of precious metals, has been principally from the Annie Laurie and Sevier mines.

Annie Laurie mine.—The Annie Laurie mine has been operated very little for several years, and most of its workings were inaccessible at the time of visit. Lindgren,[8] who visited the mine in 1904, when it was in operation, describes it as follows:

> The deposits occur in well-defined quartz veins cutting through the core of this old volcanic district. As far as known, no deposits occur in the rhyolite or in the great masses of rhyolite tuffs to the north of the Annie Laurie. They are confined to the dacite already mentioned as occurring near the mines. The Annie Laurie vein

[1] Spurr, J. E., Geology of the Tonopah mining district, Nev.: U. S. Geol. Survey Prof. Paper 42, p. 262, 1905.

[2] Schrader, F. C., Mineral deposits in the Cerbat Range, Black Mountains, and Grand Wash Cliffs, Mohave County, Ariz.: U. S. Geol. Survey Bull. 397, p. 48, 1909.

[3] Schrader, F. C., A reconnaissance of the Jarbidge, Contact, and Elk Mountain mining districts, Elko County, Nev.: U. S. Geol. Survey Bull. 497, p. 53, 1912.

[4] Lindgren, Waldemar, Graton, L. C., and Gordon, C. H., The ore deposits of New Mexico: U. S. Geol. Survey Prof. Paper 68, p. 71, 1910.

[5] Umpleby, J. B., Geology and ore deposits of the Republic mining district: Washington Geol. Survey Bull. 1, p. 42, 1910.

[6] Ransome, F. L., Geology and ore deposits of Goldfield, Nev.: U. S. Geol. Survey Prof. Paper 66, pp. 180-195, 1909.

[7] Larsen, E. S., Alunite in the San Cristobal quadrangle, Colo.: U. S. Geol. Survey Bull. 530, p. 179, 1911.

[8] Lindgren, Waldemar, The Annie Laurie mine, Piute County, Utah: U. S. Geol. Survey Bull. 285, pp. 87-90, 1906.

courses nearly north and south and dips from 45° to 60° W. About a mile to the west is a parallel vein called the Sevier, on which the Sevier Mining Co. is now erecting a mill. The extension of the Sevier toward the north is being sought for in the Holland tunnel.

The Annie Laurie vein is very poorly exposed on the surface, being largely covered by morainal material. There is, however, a large outcrop rising boldly above the Blue Bird tunnel, and this formed the point of discovery. The vein has not been found on the surface at any point north of this. Within a moderate distance north from the northernmost workings the Annie Laurie vein should enter the rhyolite. How this will affect the deposit is as yet problematical. On the surface none of the productive veins appear to occur in this rock.

The quartz forms an almost continuous sheet along the vein, rarely less than 3 feet in thickness and often expanding to a width of 20 feet or more. As a rule the walls are poorly defined and slickensides indicating motion are rare. In places it contains, parallel to the walls, streaks of iron oxides and black, sooty, manganese ores. Near the walls the vein very commonly shows brecciation, and the quartz here often contains abundant and sharply defined inclusions of country rock. While it is almost impossible to obtain fresh rock at any place in the mine, and chloritization as well as carbonatization have frequently occurred, the rock is not changed very much in appearance, and the included greenish fragments are sharply outlined against the white quartz.

The mine workings have not penetrated below the zone of oxidation, and neither the quartz nor the country rock seem to contain any unoxidized sulphides. In only one place, in the crosscut of the lowest tunnel, was some fresher dacite found which contained specks of pyrite.

In addition to the regular vein, which is often referred to as the East vein, there is also in certain parts of the workings a smaller fissure which lies a short distance to the west and which differs in some respects from the former. Its quartz contains more gold, its vein is narrower, and slickensides appear sometimes on the walls. It is principally known from No. 3 tunnel, in the richest part of the vein.

Two faults with a throw of 20 and 40 feet are known on the Blue Bird and No. 4 levels, but on the whole the vein is little disturbed.

The ore consists of a white, normal vein quartz, often very friable, breaking easily into small fragments. It is sometimes drusy but more commonly massive. Calcite is abundant in certain parts of the deposit but has often been dissolved by surface waters, leaving a hackly or lamellar quartz of striking appearance. As a rule no ore minerals are visible, although on panning the quartz may yield a little visible gold.

The pyrite which the ore contained is doubtless converted to limonite, while the decomposition of the carbonates has resulted in the formation of oxides of manganese as well as more limonite. A slight copper stain appears in places, especially where the ore is rich. Finely divided argentite is no doubt present, but only in small quantities. On concentration the ore yields a very small quantity of sulphides, which are extremely rich in silver.

The value of the gold in the ore exceeds that of the silver. Samples of ore of the East vein yield, for instance, gold, $12; silver, $2.30; or gold, $5.60; silver, $2.05. Samples from the West vein contain, for instance, gold, $11; silver, 32 cents; or gold, $4.80; silver, 68 cents. The richest ore is stated to assay from $15 to $18 per ton, odd samples frequently rising to $100 per ton. The average value of the ore is said to be between $7 and $8 per ton. The bullion obtained from the zinc boxes is stated to be 0.925 fine. One analysis shows 230 parts of gold, 695 parts of silver, 65 parts of zinc, and 10 parts of copper, the zinc being derived from the shavings in the boxes. The average bullion would contain about 750 parts silver and 250 parts gold. * * *

The ore shoots of the Annie Laurie vein have an ill-defined lenticular form when projected on the plane of the vein, and appear to pitch 45° or less to the north. Some of them at least have cores consisting of bunches of rich ore, gradually decreasing in tenor toward the outside. On No. 3 level in the shoot the vein is in places 23 feet wide.

Sevier mine.—The Sevier vein strikes nearly north and dips rather steeply east. The ledge can be followed by interrupted outcrops for fully 3,000 feet and in its greatest development exceeds 30 feet in width. The ore occurs in shoots that are irregular in form and very variable in size. The vein matter of the ledge is quartz with considerable carbonate and some adularia, together with iron oxide that has resulted from the oxidation of sulphides. The vein quartz has the lamellar form and hackly fracture characteristic of this type of vein. Lindgren[1] says:

> The ore of the Sevier mine is in general similar to that of the Annie Laurie, although a drusy structure is more common; in places well-crystallized masses of amethyst-colored quartz appear. * * * A considerable amount of argentite is present in finely divided form, and panning also yields a little fine gold.

At the time of the writer's visit the ore was being extracted from an open cut. At depth, in some places at least, the vein quartz has apparently given place to silicified country rock with small stringers of quartz, but whether this condition is local or general can not be stated.

The ore is treated at a mill on the property by amalgamation and cyanidation.

OHIO DISTRICT.

By B. S. Butler.

The Ohio mining district has never made a large production, though it has been the scene of considerable development. The Bully Boy and Webster mine has been the largest producer, and the Cascade, Shamrock, Dalton,

[1] Op. cit., p. 90.

Wedge, and others have made small productions.

Bully Boy and Webster mine.—The principal workings of the Bully Boy and Webster mine have been on two veins, striking generally north and dipping steeply west. The country rock is quartzite and porphyritic lava. The veins evidently occupy fault fissures, for in the west vein the quartzite has been faulted against the lava in a part of the developed area. The vein is in part inclosed in the volcanic rocks, in part lies between quartzite and lava, and at the south end of the tunnel is wholly in quartzite.

The vein filling is mainly quartz, with subordinate amounts of carbonate, fluorite, and barite. The carbonate in places becomes abundant. The vein is in many places indistinctly banded, indicating that it was formed in an open space. The pay ore is in irregular shoots that occur in any part of the vein.

The ore varies considerably in mineralogy and metal content. The west vein contains lead and some copper, gold, and silver. The east vein is richer in gold and in the upper levels, at least, contains less lead. The upper levels have yielded some very rich gold-silver ore.

In the upper levels the ores have been oxidized, the lead and copper being present largely as carbonates. In the lower levels the lead is galena and the copper minerals are chalcopyrite and tetrahedrite. Manganese is abundant in all parts of the mine but especially in the quartzite on the lowest level of the west vein. In most parts of the mine it is present as hydrous oxide, but in the south end of the lower tunnel the vein is made up largely of a brown carbonate that yields oxides of iron and manganese on weathering. In the rich gold ore the gold is in part native and in part probably combined with silver as telluride and selenide. Both tellurium and selenium are present in the ore.

The ore at present developed in the mine is of milling grade. A mill was built on the property in 1913 and some ore concentrated. It was later destroyed by fire.

Shamrock mine.—The Shamrock mine is in a vein of quartzite that strikes northwest and dips steeply southwest. The vein filling is quartz and some carbonate with chalcopyrite, tetrahedrite, and galena. The sulphides have been partly oxidized. The ore occurs as irregular shoots in the vein. Development has been by two tunnels, about 70 feet apart vertically, with raises and winzes in the ore shoots. It is reported that a few carloads of ore have been shipped from the mine.

Cascade mine.—The Cascade mine is developed in a vein in quartzite that strikes west of north and dips steeply west. The vein filling is quartz, with some carbonate, as in the other veins of the district. The sulphide minerals are chalcopyrite, tetrahedrite, galena, and sphalerite, all of which are partly oxidized. The ore, as in the other mines, contains gold and silver. It is reported that some has been shipped. The deposit is developed by several hundred feet of tunnel, with raises and winzes.

Deseret mine.—The Deseret mine, east of the Bully Boy, is in a parallel vein and the ore is apparently of the same general character, though the works were not accessible at the time of visit.

Dalton mine.—The Dalton mine has long been idle and the workings were not examined. It is in a north-south vein, apparently of quartz carbonate, similar to other veins of the district, except that it contains rhodochrosite. Tetrahedrite and pyrite are plentiful in some specimens of ore. The mine produced a few thousand dollars' worth of rich gold-silver ore and a mill was erected in Bullion Canyon for the treatment of the lower-grade material, but little ore was treated in this mill.

Wedge mine.—The Wedge vein is a quartz-carbonate-adularia vein in the volcanic rocks. It is reported that a small amount of rich gold-silver ore was mined near the surface. Since the writer's visit additional ore has been developed and shipped. There are other prospects in the district and probably small production has been made from other properties.

MOUNT BALDY DISTRICT.

By B. S. Butler.

Deertrail mine.—The Deertrail mine has made the largest production of any mine in the district. It is a replacement deposit forming an irregular flat-lying body in limestone just above heavy bedded quartzite. The high-grade ore consisted principally of the oxidation products of galena and pyrite with a high gold and silver content. The milling ore is a friable material composed of sericitic

muscovite, quartz, and hydrous iron oxide and owes its value to gold and silver. The amount of this class of ore is large, but its character renders the saving of the gold and silver difficult. In the early eighties a mill in Bullion Canyon treated 6,000 to 7,000 tons of ore, but the loss in tailings was high. At a rough estimate the value of the metal produced from all ore mined is about $150,000.

The fine sericitic mica of this deposit could probably be washed and sold if it were not for the cost of transportation. A mill was built and put in operation on the property in 1918.

Lucky Boy mine.—The Lucky Boy quicksilver deposit which has replaced limestone consists of ticmannite and onofrite. Its general character is described on page 551.

Clyde mine.—The Clyde mine is developed on a fissure vein striking west of north. The mine was idle at the time of visit and the workings were not examined. The ore on the dump consists of pyrite, chalcopyrite, tetrahedrite, sphalerite, and wurtzite in a gangue of quartz with some carbonate. The vein is developed by a winze from a tunnel several hundred feet above the bottom of Cottonwood Canyon. A second tunnel was driven near the bottom of the canyon, but no ore is reported. The mine is reported to have shipped a few carloads of copper-silver-gold ore.

Crystal mine.—The Crystal mine on the south side of Little Cottonwood Canyon is developed in veins in quartzite. The ore is reported to have carried lead with gold and silver. A mill was constructed on the property, but little ore was treated.

There has been considerable prospecting in the district by other companies but no large production of ore. The alunite veins of the district (see p. 546) have yielded considerable potash and are a possible source of aluminum.

Krotki iron mine.—The Krotki iron mine in the Antelope Range (see p. 546) has produced some iron and manganese ore, which has been shipped to the valley smelters for flux.

NEWTON DISTRICT.

By B. S. Butler.

There has been prospecting at numerous points in the Newton district, but only the Rob Roy and Sheep Rock mines have been productive.

Rob Roy mine.—The Rob Roy mine is near the contact of the intrusive quartz monzonite porphyry and the overlying volcanic rocks, both of which have been fissured and the fissures filled with vein quartz. Adjacent to the veins the rocks have been extensively altered and in many places silicified and pyritized. The Rob Roy vein strikes about north and dips west at a rather low angle. The mine has produced a little rich gold ore.

Sheep Rock mine.—The Sheep Rock mine is about 3 miles south of the Rob Roy. According to Loughlin the geologic conditions are as follows:

The country rock is andesitic porphyry, which is all more or less sericitized and pyritized and in places is highly silicified. At the bottom of the Sheep Rock shaft (300 feet deep) the sericite rock contains patches of calcite and fluorite. The rock on the surface is largely reduced to "float." This float contains much vein quartz, and it is surprising that it has led to so little prospecting.

The Sheep Rock vein, which alone has been prospected and developed, strikes north to N. 20 E. and dips 65° to 70° E. The vein matter is quartz, in part slightly amethystine and containing remnants of unreplaced calcite, and preserves in part the shattered structure of the country rock. The quartz is full of cavities lined with crystals and is characterized by the hackly structure where partly replaced calcite has been removed.

The only ore minerals recognized are pyrite (or limonite pseudomorphs), native gold, and a fine dark material said to be argentite or cerargyrite (horn silver). The pyrite forms small cubes and grains both in the white comby quartz and in the silicified porphyry. The gold and silver minerals were seen only in pannings from the high-grade ore, although specimens with visible gold were seen in Mr. W. A. Wilson's office in Salt Lake City. Some ruby silver is said to occur in thin seams. Tellurium also has been reported.

The vein is all oxidized, so far as it has been worked, to the 300-foot level. Ore has been mined from the surface, where it was 5 feet thick, down to the 300-foot level, where its maximum width is 25 feet. The ore of shipping grade occurs in shoots, and is usually found associated with prominent black stains of

hydrous manganese oxide. Picked samples of this ore have assayed more than a thousand dollars a ton, but the average shipping ore probably ranges from $50 to $100.

The parts of the vein inclosing the high-grade shoots and also the adjacent pyritized rock carry some gold and silver in pyrite and at the time of visit were being treated in an experimental 5-stamp mill with encouraging results.

Placer ground in the vicinity of the Sheep Rock mine has been prospected recently, but no definite results have been reported.

Veins containing tungsten in the form of wolframite are reported as occurring near the head of North Creek.

FORTUNA DISTRICT.

By G. F. Loughlin.

Considerable excitement prevailed in the summer of 1914 over the discovery of gold ore at the camp of Fortuna in the foothills about 10 miles north of Beaver City at the mouth of Rocky Hollow. When the writer visited the camp for a few hours on September 9, 1914, it consisted of 11 or 12 tents and 1 or 2 tent wagons.

The developments on different properties include two tunnels each less than 100 feet long and several smaller prospects. Prospecting has continued during the fall and winter, and encouraging results have been reported in press notices, but little or no ore has been shipped.

The country rock, so far as seen, is andesitic porphyry, mostly extrusive. Several dikes clearly cut the extrusive rock.

The deposits are replacement veins similar to those at the Sheep Rock mine and in the Marysvale district. The principal gangue minerals are quartz (with adularia?) and calcite, the quartz replacing the calcite, where both are found together. Quartz is in places the only megascopic gangue mineral, occurring both as distinct crystals around cavities and as dense forms replacing the wall rock. The dense variety has the same appearance as the quartz-adularia aggregates in the Marysvale veins, but no adularia was detected in the powdered Fortuna material.

The ore minerals recognized are limonite (the oxidation product of pyrite) and native gold, which may be recovered by panning oxidized ore. The limonite occurs in thickly scattered minute cubic grains (pyrite pseudomorphs) which are mostly in replaced porphyry within or adjacent to the veins. Little or none was noted in the well-crystallized quartz.

All the ore thus far found has been oxidized, and the most promising material seen consisted largely of soft vein material heavily stained with manganese and iron oxides. No assays of the ore were obtained.

The deposits plainly belong to the quartz-adularia type, which, as a whole, varies greatly in value, some veins being productive and others practically barren. Development can alone determine their economic probabilities in a new district.

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SALINA CREEK DISTRICT.

By G. F. Loughlin.

The Salina Creek district is in the western foothills of the Wasatch Plateau east of Salina, a town on the San Pete Valley branch of the Denver & Rio Grande Railroad. The Lead Hill, the only mine for which production has been recorded, is on the north side of the canyon of Salina Creek, about 4 miles east of Salina. This mine produced lead ore and concentrates from 1908 to 1912.

GEOLOGY.

SEDIMENTARY ROCKS.

The district lies in a very interesting part, geologically, of the Plateau province. The sedimentary rocks represented are of Jurassic, Cretaceous, and early Tertiary (Eocene) age and are capped in places by andesitic lavas. (See fig. 61.)

The Jurassic rocks, according to Richardson,[1] form a band about 2 miles wide, extending northeastward in a range of low barren hills from Salina Creek, just east of the town, for 11 miles to Mayfield. They consist of a considerable but undetermined thickness of fissile shales, generally drab in color but locally red, and of a few intercalated layers of drab sandstone a few inches to several feet in thickness. Lenses of gypsum and rock salt are irregularly interbedded throughout the formation. Both sides of the Jurassic in this district are bounded by faults and abut against Eocene strata.

The Cretaceous in the region is represented by beds of Colorado and Montana age. Only the Colorado is exposed within the district proper, but the Montana occupies a large area drained by the upper part of Salina Creek. The Colorado deposits outcrop in the bottom of the canyon of Salina Creek, from beneath a considerable thickness of Eocene beds, about 4 miles east of Salina. They consist of thin-bedded buff sandstone ranging in color from gray through yellow, purple, and red; some from subordinate drab, purple, and green shale carrying *Inoceramus labiatus*;[2] a few thin beds or lenses of fine conglomerate, containing pebbles of quartzite and chert; and some calcareous beds. The strata range in hardness from loosely coherent sands to semiquartzites. At their western limit they stand almost vertical and are directly overlain by nearly horizontal Eocene beds. The dip flattens eastward, and at Rattlesnake Hill, 1½ miles east of the mine, it is 30°–40° E.

Eocene strata form a line of low ridges along the west side of the Jurassic area, and cover a large area extending eastward from the Jurassic area for 6 miles and more. They consist of at least 2,000 feet of drab, green, and red shales, reddish-buff and gray sandstones, and whitish fresh-water limestones. The stratigraphy is varied, and even adjacent sections are rarely alike. Numerous fresh-water fossils, including *Sphaerium*, *Planorbis*, *Physa*, *Goniobasis*, and *Vivipara*,[3] occur in these rocks, which are referred to the Wasatch formation of the Eocene. Near the Lead Hill mine red and white cliff-forming sandstones are overlain by gray to greenish shales and sandstones, and by cherty limestone, which caps the hills. The red and white sandstones carry the ores of the mine. They thicken somewhat to the east, and expose lower and lower beds, suggesting a westward overlap on the Colorado beds. The dip along Salina Creek is prevailingly 2°–3° W. but varies locally, and at the mine is northeastward.

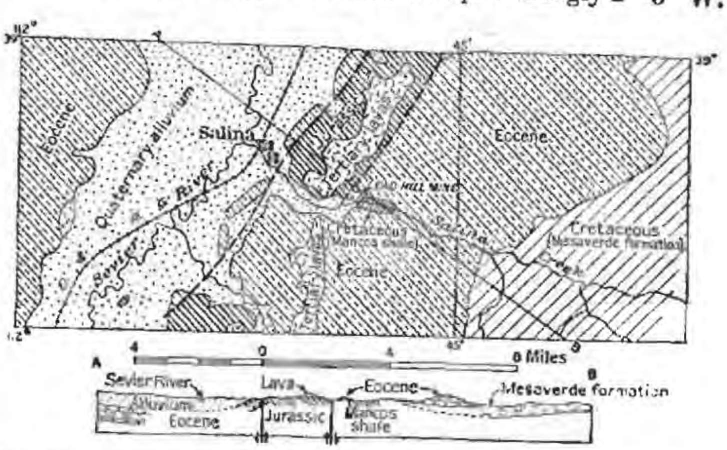

FIGURE 61.—Geologic map and section of region around Salina. After G. B. Richardson.

IGNEOUS ROCKS.

The lavas in the district are exposed in two masses, each 4 or 5 miles long and 1 to 2 miles wide. One trending northeastward caps the upturned Jurassic beds just north of Salina Creek; the other, trending southward, caps the nearly horizontal Eocene beds directly to the south. Both masses are correlated with the extensive lavas to the south and are assigned to the Tertiary. The fact that they rest directly upon Jurassic strata implies that the Eocene had been removed from this part of the district before they were erupted. They include rhyolite and andesite and are somewhat weathered but are free from the propylitic alteration that characterizes many such rocks when permeated by ore-forming solutions.

[1] Richardson, G. B., Underground water in the San Pete and central Sevier valleys, Utah: U. S. Geol. Survey Water-Supply Paper 199, p. 8, 1907.

[2] Idem, p. 9.

[3] Idem, p. 10.

STRUCTURE.

The faults of the Sevier fault zone which bound the block of Jurassic beds thrust up against the Eocene are marked by narrow tributary canyons trending about N. 30° E. Other faults of northeasterly, northerly, and easterly trends have been noted north and east of the Lead Hill mine. Their relations to the Sevier fault zone have not been determined.

Little is known of the relation of these faults to mineralization. A vein 3 to 4 feet thick of chertlike replacement quartz was found approximately in line with the eastern member of the Sevier fault zone, in Twist Canyon, half a mile or more north of Salina Creek. The vein strikes N. 35° E., dips southeastward, and cuts a dense impure limestone bed of the upper member of the Eocene. The rock along a north-south fault east of the Lead Hill mine is said to be mineralized, but no fissures of importance have been found associated with the ore of the mine, which impregnates a calcareous sandstone bed. Small amounts of ore have been found in the vertical Colorado (Cretaceous) beds close by the mine workings, and suggests that fissures at this place coincide with the vertical bedding.

ORE DEPOSITS.

LEAD HILL MINE.

The workings of the Lead Hill mine, totaling about 800 feet of drifts and inclines, are in a basal bed of Eocene sandstone, locally white, which, as a rule, is separated from the underlying Colorado beds by a red material that has no definite structure and suggests an old residual soil. This material, however, is absent through much of the mine, which is in an old erosion channel on the Jurassic surface. The ore is lead-zinc sulphide with little or no silver and with local streaks and bunches of oxidized copper ore. It is all of milling grade. Small shipments of lead concentrates and copper concentrates have been made.

The mineralized sandstone is mostly medium grained but is conglomeratic in places. Its principal constituents are grains of quartz, microcline, plagioclase, and muscovite and fragments of calcareous sandstone, shale, and quartzite, with small amounts of garnet, zircon, biotite, titanite, and chlorite. The matrix is calcite. The ore and gangue minerals, which replace the calcite matrix in lenses and streaks through a vertical thickness of 6 feet, are galena (accompanied by a little cerusite), zinc blende, a little pyrite, chalcocite, malachite, azurite, and celestite (strontium sulphate). No chalcopyrite was found. Little or no replacement of the sand grains has taken place.

Concentration is effected in a 5-stamp mill but is considerably hampered by the presence in large amount of gangue minerals of rather high specific gravity. The middlings from the mill consist of much zinc blende (specific gravity 3.5 to 4), a rather small amount of galena (7.5), a little cerusite (6.5), pyrite (5), chalcocite (5.7), and malachite (4); considerable celestite (4), garnet (4), calcite (2.7), quartz (2.65), feldspar (2.6 to 2.7), a little zircon (4.7), and biotite (2.8). The middlings thus make a zinc ore, which can not be cleanly freed from gangue, although it may be better separated than it is from minerals with a specific gravity of less than 3.

The heads consist of galena and cerusite, considerable zinc blende, and minor amounts of pyrite and the other minerals named above. They are said to contain 38 per cent lead. The differences in specific gravity suggest that a better separation of the lead minerals from zinc blende and gangue is possible.

The celestite, whose presence as a gangue mineral in Utah ore deposits is unique, is colorless to white and ranges in size from fine irregular grains up to poikilitic crystals 2 or 3 millimeters long that inclose unaltered sand grains. It occurs with galena and blende, and in the average middlings it and the zinc blende are the most prominent minerals. The two are so nearly equal in specific gravity that mechanical separation of them is difficult. The celestite, however, is also found nearly free from metallic minerals, as shown in the analysis below.

Chemical analysis of celestite concentrates, Lead Hill mine, Salina Creek, Utah.

[R. C. Wells, analyst.]

SiO_2	6.9
TiO_2, etc.	1.0
Al_2O_3	.6
Fe_2O_3	.3
FeO	.3
SrO	45.8
CaO	.9
MnO	Trace.
BaO	None.

CO_2	1.9
SO_3	34.8
H_2O	.3
PbO	6.6
	99.4

Mineral composition[1]	
Quartz	4.9
Rutile and titanite	1.0
Feldspar and sericite	2.6
Garnet, chlorite, and tourmaline	1.5
Calcite	1.4
Limonite	.4
Celestite	80.8
Cerusite	7.9
Water	.2
	100.7

If considerable celestite can be found free from metallic minerals it may serve as a source of strontium, which is employed in one process of sugar manufacturing, in the making of fireworks and signal lights, and in several other chemical industries.

GENESIS OF THE ORES.

The genesis of the ore is uncertain. The mineral composition of the ore is, with the exception of celestite, similar to that of other lead-zinc deposits low in silver, some of which are directly though not closely associated with intrusive igneous rocks. The failure of the ore to replace any other minerals than calcite is also characteristic. The mineralized fissures suggest that some mineralization may have been effected by ascending solutions from a possible igneous source, and the slightness of the mineralization along vertical bedding planes in the Colorado formation further suggests that locally solutions rose along these bedding planes to the Eocene contact and then spread along the basal calcareous sandstone bed. On the other hand, there is nothing at present known to prevent acceptance of the view that the ore was concentrated from the overlying strata by a process similar to that which formed the copper deposits in the "Red Beds" of the Plateau region. It must be admitted, however, that though copper deposits in the "Red Beds" are abundant, no galena-blende deposits in these beds have previously been described.

According to either view the Lead Hill deposit is exceptional. It differs, however, from other lead-zinc deposits of Utah only in being in calcareous sandstones instead of in limestones.

[1] Based on the analysis and on microscopic study.

Its similarity to these deposits and the absence in the Plateau region of lead-zinc deposits that can be attributed with a fair degree of certainty to descending waters favor the conclusion that it was formed by ascending solutions that had become so cooled and perhaps so diluted by descending waters that they had already lost practically all their silica and precious metals.

COYOTE DISTRICT.[1]

By G. B. Richardson.

LOCATION.

Coyote Creek, a branch of the East Fork of Sevier River, occupies a short, narrow valley in the northwestern part of Garfield County, in the midst of the High Plateaus of Utah. The mining camp is about 40 miles by road southeast of Marysvale, the terminus of the San Pete & Sevier branch of the Rio Grande Western Railway. The elevation of the mines is about 7,000 feet and that of the Awapa Plateau to the north and the Aquarius Plateau to the south and east is 2,000 to 3,000 feet higher.

GEOLOGY.

The general geology of the region has been described by Dutton.[2] The igneous rocks consist of lava sheets, beds of tuff and volcanic conglomerate, and intrusive masses. They cap the highest plateaus and overlie an eroded surface of Eocene strata which outcrop at lower elevations around the igneous uplands. Beneath the Tertiary rocks lie several thousand feet of Mesozoic and Paleozoic sediments, which are exposed in a series of descending benches southward from the High Plateaus to the platform in which Colorado River has cut the Grand Canyon. The igneous plateaus are traversed by a number of normal faults of large displacement which trend in general north. One of these faults, aided by erosion, has exposed in the Coyote Creek valley a small area of Eocene sediments in which the antimony occurs.

The valley of Coyote Creek is occupied by a variable succession of strata. At the base of the section is 150 feet of a gray conglomerate composed of a sandy matrix containing rounded

[1] Reprinted with slight emendations from U. S. Geol. Survey Bull. 340, pp. 253-256, 1908. There has been no extensive production or development since the description was written.

[2] Geology of the High Plateaus of Utah, U. S. Geog. and Geol. Survey Rocky Mtn. Region, 1880.

quartz and quartzite pebbles whose maximum diameter is 6 inches. This conglomerate is overlain by a great mass of fine-textured buff and reddish sandstone and subordinate drab and red sandy and clayey shale and thin-bedded limestone, amounting in all to several hundred feet. No fossils have been found in these rocks, but they are provisionally referred to the Eocene because of their lithologic resemblance to other Eocene strata in the Plateau region. They are overlain by about 1,000 feet of andesitic tuff and lava, which caps the surrounding plateaus. The rocks are approximately flat, having only a general low northeastward dip. At the mouth of Coyote Canyon a fault causes the strata to dip steeply westward.

ORE DEPOSITS.

The occurrence of antimony in southern Utah has long been known—Huntley says that the deposits were located in May, 1879. They have been worked at irregular intervals since 1880 and it is reported that more than $100,000 worth of ore has been shipped from the property on Coyote Creek, in Garfield County, which has been described by Blake.[1]

The ore consists of stibnite and its oxidation products, which occur generally in flat-lying deposits in the sandstone and conglomerate. The chief zone of mineralization is adjacent to the contact of the conglomerate and overlying sandstone, the ore occurring most commonly in fine-textured argillaceous sandstone a few feet above the conglomerate. In many places a bed of clay shale about 5 feet thick immediately underlies the ore-bearing sandstone, and locally the upper part of the conglomerate is mineralized. The ore does not occur persistently and uniformly, though it is present most commonly at this general horizon on both sides of Coyote Creek.

In the early days of development attention was given chiefly to the lenses of ore, the "kidney" deposits. The known lenses have all been worked out but are said to have ranged from several inches to 20 feet in thickness. One of them is said to have yielded 55 tons of ore. No large bodies of stibnite are in sight now, but there is much low-grade ore.

The occurrence and character of the deposits differ in the different prospects. A common occurrence is in layer-like bodies of irregular thickness but averaging only a few inches. The "layers" are not continuous and are only approximately parallel to the bedding. Many of them are undulatory and thicken and thin out irregularly. In a number of places thin bodies of ore cut across the bedding of the sandstone and connect the more nearly horizontal deposits. The ore also commonly occurs disseminated in the sandstone in irregular segregations.

A characteristic feature of the antimony deposits of Coyote Creek is that the ore consists only of stibnite and its oxidation products, gangue minerals being almost completely absent. Only one exception was observed, at the Emily claim, on the south side of the creek, where in a small gash vein only a few inches wide stibnite and pyrite are associated with calcite. A thin section cut along the contact of the stibnite with the country rock shows an uneven junction, the stibnite extending very irregularly into the sandstone. Locally stibnite, with well-defined crystal faces, penetrates and is partly embedded in adjacent quartz grains of the sandstone.

The stibnite occurs in several forms. In the larger ore bodies it commonly forms aggregates of prismatic crystals arranged radially or in columnar masses. In one group crystals 6 inches long were observed. It also forms indiscriminately mixed groups of acicular crystals. Adjacent to the outcrop it is almost universally oxidized, the steel-gray sulphide giving place to the lighter brown, yellow, and white oxidation products. W. T. Schaller, of the United States Geological Survey, who examined a number of oxidized-ore specimens, reports that they are anhydrous and easily fusible and that they are either valentinite or senarmontite—probably the former, as reported by Blake.[1] In many places the valentinite occurs in acicular crystals as a pseudomorph after stibnite. Locally associated with the ore and forming efflorescences on the walls of the country rock are epsomite; a hydrous aluminum sulphate, probably alunogen; a hydrous ferrous sulphate; and gypsum.

Small quantities of arsenic minerals have been found in the valley of Coyote Creek contiguous to the antimony deposits, but so far as known not immediately associated with

[1] Blake, W. P., U. S. Geol. Survey Mineral Resources, 1883 and 1884, pp. 643-644, 1885.

them. On the north side of the creek, about 100 feet southeast of the stibnite prospect known as "Black Jack No. 2," there is a small deposit of the sulphides of arsenic in shales of Eocene age. Realgar and orpiment in irregular seams ranging in thickness from a fraction of an inch to about 6 inches and only a few inches in length occur in a blue-drab clay shale. No other vein minerals are present, and the realgar and orpiment, in small crystals, are intimately associated. Other similar small deposits of arsenic are reported from the valley of Coyote Creek.

The antimony ore is epigenetic—that is, it was formed subsequently to the deposition of the rocks in which it is found, and its origin is probably connected with the adjacent igneous rocks, as suggested by Blake. The antimony may have been derived from these rocks either during their intrusion through the sediments or less probably after their eruption on the surface, the stibnite being deposited from percolating solutions in part filling existing spaces and in part by metasomatic replacement. The bed of shale which in many places immediately underlies the ore apparently arrested the solutions and determined the local concentration of the stibnite. In such places the solutions were evidently not directly ascending but were moving either laterally or downward.

The deposits of antimony adjacent to Coyote Creek have been worked sporadically for the last 27 years. For the most part this work has been limited to the exploitation of the large lenses and little or no systematic mining has been done. There has been considerable prospecting, however, and a score or more of tunnels have been driven into the deposits at various places on both sides of the creek.

In the past work has been chiefly directed toward getting high-grade ore running between 50 and 60 per cent of antimony. The "Kidney" deposits were exploited, and hand-sorted ore was shipped. One attempt was made to smelt the ore on the property but proved unable to meet competition.

It is difficult to estimate the amount of available antimony. The dumps and tunnels of the old prospects show a great amount of low-grade ore, and the problem is how to handle it economically.

GOLD SPRINGS AND STATE LINE DISTRICTS.

By B. S. Butler.

GEOGRAPHY.

The Gold Springs and State Line districts are on the Utah-Nevada State line at about latitude 38°. The nearest railroad point for both districts is Modena, on the Los Angeles & Salt Lake Railroad, about 10 miles in a direct line and about 16 by road from Gold Springs and about 17 miles from the State line. The districts are in an irregular group of volcanic hills—a southern extension of the Snake and Cedar ranges—whose elevation varies from about 6,000 to 7,000 feet, with a few points rising above 7,000 feet.

There are no large streams in the range, but small streams and springs furnish water throughout the year suitable for domestic purposes and have been utilized in the metallurgic plants in the treatment of the ores.

The mountains support a rather plentiful growth of cedar and other scrubby trees, which furnish an abundant fuel supply and are utilized to some extent for timber in the mines.

GEOLOGY.

IGNEOUS ROCKS.

All the rocks of the districts are igneous and all, so far as determined, are extrusive. They may be readily separated into three general groups—latite, rhyolite, and rhyolite tuff—each of which would doubtless be subdivided on detailed study.

The latite is exposed in the lower areas in the vicinity of Gold Springs and westward to Fay and Deer Lodge, Nev. The rock is commonly porphyritic, containing rather abundant phenocrysts of plagioclase (oligoclase) and fewer of orthoclase. Quartz phenocrysts are commonly absent. Some dark mineral, which was rather abundant in the specimens examined, has been altered to chlorite, which gives the rock a distinct greenish color. Probably both biotite and pyroxene were present. The groundmass is too fine for determination of the constituent minerals, though it is for the most part crystalline.

The rhyolite forms the higher elevations in the Gold Springs district and is the prevailing rock to the north in the State Line dis-

trict. In the Gold Springs district it is especially well exposed on the higher parts of Buck Mountain and Bull Hill. The rhyolite is commonly much less massive than the latite and a thin platy structure is common. All the beds contain fragments of tuff and many, especially in the eastern part of the State Line district, are distinctly tuffaceous. The rhyolites are too fine grained for their composition to be determined except by chemical analyses and they may prove to be in part quartz latites. The more massive beds contain rather abundant phenocrysts of quartz and fewer of orthoclase and plagioclase. The less massive and tuffaceous beds are composed largely of glass. The rhyolites were not traced from the Gold Springs district to the State Line district, but the similarity of the rock at the two localities is strong indication that they are to be correlated.

The rhyolitic tuff lies south of Deer Lodge, both north and south of the old Pioche road, in extensive fine-grained white to yellowish beds containing a few thin obsidian flows. Its relation to the other rocks of the district was not determined, but it seems to correspond to the rhyolite tuff described by Spurr [1] from Meadow Valley to the southwest. If this suggested correlation be correct the tuff is probably the oldest rock exposed in the region.

STRUCTURE.

The area does not appear to have been affected by extensive folding or faulting. The formations appear to be essentially horizontal, though careful mapping would doubtless show considerable irregularity.

Fissuring has been extensive and has involved some movement, though the similarity of the wall rocks over considerable thicknesses makes it difficult to determine its amount. In the southern part of the area, about Gold Springs, Fay, and Deer Lodge, nearly all the fissures trend north. Farther north, in the State Line district, they trend much more irregularly, some of the most conspicuous trending east. Most of the north-south fissures dip 50° to 70° E. in the Gold Springs district, but farther west many of them dip west. The fissures are strong and the silicification of the rocks adjacent to them has caused their position to be marked by prominent outcrops, many of which can be followed for several hundred feet; the great fissure about 1½ miles west of Deer Lodge can readily be traced for 2 to 3 miles and with less certainty for a considerably greater distance.

HISTORY AND PRODUCTION.

By V. C. Heikes.

EARLY WORK.

The old stage road from Frisco to Pioche passes through the area, and the prominent ledges that mark the fissures must have been seen by many prospectors and mining men during the early days at Pioche. These early visitors, however, do not seem to have been attracted by the ledges, probably because most of them were in search of lead-silver ores, for which limestone was considered the most favorable formation, and also because placers are not associated with the gold deposits of this region and no gold was revealed by the panning of the gravels. It was not till 1896, therefore, that prospecting began in the State Line district and was quickly extended over the area, for most of the fissures outcrop prominently and preliminary prospecting proved relatively easy.

For several years subsequent to the discovery there was considerable activity. Mills were built for treating the ore and there was a considerable production of gold and silver. Many of the ore shoots, however, decreased in size and metal content with increased depth, and this, together with the necessity of pumping, resulted in the closing of most of the mines.

STATE LINE DISTRICT.

The State Line district, in Iron County, 17 miles northwest of Modena, on the Los Angeles & Salt Lake Railroad, was organized in the summer of 1896. An amalgamation mill built by A. Popkiss soon after the opening of the district was sold in November, 1898, to the company operating the Johnny property for the treatment of its low-grade ore. Better ore was shipped direct to smelters. This mill was moved in 1912 to the Big Fourteen claims, where some ore was tested.

The Ophir mill, which was started in November, 1901, treated 150 tons of ore per day by the Russell lixiviation process and later by the

[1] Spurr, J. E., Descriptive geology of Nevada south of the fortieth parallel and adjacent parts of California: U. S. Geol. Survey Bull. 208, p. 148, 1903.

cyanide process. Neither process was successful and the mill was closed in 1902.

GOLD SPRINGS DISTRICT.

The Gold Springs district lies along the Utah-Nevada State line in Iron County, 17 miles northwest of Modena, a station on the Los Angeles & Salt Lake Railroad. The Jennie property, the only producer whose records are available, was the mainstay of the district from 1907 to 1909, producing several thousand dollars' worth of gold and silver from the ore in a mill first designed for amalgamation and later widened to include the cyanidation process for the treatment of tailings. In fineness the bullion produced ranged from 0.687 to 0.526 in silver and from 0.274 to 0.385 in gold. Between 1907 and 1911 the district is credited with the production of 12,189 tons of ore, yielding $48,118 in gold and 8,441 ounces of silver, valued in all at $52,903.

ORE DEPOSITS.

By B. S. Butler.

OCCURRENCE AND CHARACTER.

The ores occur in well-defined veins. In the Gold Springs district they strike in general north and dip east. From east to west the principal veins are the Jumbo, about a mile east of Gold Springs; the Independence, about one-fourth of a mile west of the Jumbo; the Jennie, about half a mile west of Gold Springs; the Talisman, about 600 feet west of the Jennie; and the Snowflake, 1,000 to 1,200 feet west of the Talisman. Several other veins do not outcrop prominently and have been only slightly prospected. Farther north and west, near Fay and Deer Lodge, Nev., are other fissures of the same general trend and character. The most extensively developed are those on which the Horseshoe and Homestake mines are located. Some prospecting has been done on the Iris, on the Deer Lodge, on a prominent fissure west of Deer Lodge, on Bull Hill, and elsewhere.

In the Gold Springs district the most productive fissures have been found in the latite and the opinion seems to prevail that they do not extend into the rhyolite. This is not correct, however, as prominent fissures near the summit of Bull Hill are certainly in the rhyolite and contain gold, though they have been little prospected and, so far as known, have yielded no production. The latite seems to be the more favorable rock for the deposition of ores, but this is by no means demonstrated, for in the southern part of the Gold Springs district and farther to the north in the State Line district some of the best deposits have been found in the rhyolite.

The veins for the most part have formed as a filling of open fissures and are distinctly "banded" or crustified. The composition of the vein filling differs greatly in different veins and from place to place in individual veins. Quartz, usually fine grained and in many places chalcedonic, is probably the most abundant mineral. Many small cavities in the veins are lined with well-crystallized quartz, and much of it has replaced carbonate and has a characteristic lamellar or hackly structure. Next in abundance to quartz is a carbonate that is probably largely calcium carbonate, though stains on its weathered surfaces show that it contains some iron and manganese. This carbonate differs considerably in appearance and probably also in composition at different localities. Some veins are composed very largely of this mineral, others contain it abundantly in some areas; and still others have a structure that shows that it has been replaced by later minerals.

Next to the carbonate in abundance is the vein-forming feldspar adularia, which, like the quartz, has commonly formed as a replacement of the carbonate. Where abundant it gives a yellowish color to the ore and is sometimes known as "yellow quartz." It occurs in well-formed crystals and also as irregular masses that do not show definite crystal outline. Locally it forms 50 per cent of the vein filling, but in most places is much less and in many is not present at all.

Fluorite is more variable in occurrence. It was noted in many of the veins but usually in small amount. It was observed most abundantly in a prospect near the summit of Bull Hill, where it was the prevailing mineral in parts of the vein. Most of it is a deep lilac color, though some of it is pale green.

At the time of visit the best opportunity for observing the relation of the different minerals was where ore was being extracted.

With regard to economic value, the vein material in the Jennie mine can be roughly separated into white finely crystalline quartz containing little metal; into a yellowish mix-

ture of quartz, carbonate, and adularia, commonly designated as "yellow quartz" and containing the most metal; and into the coarsely crystalline almost barren carbonate. In mining, the carbonate and the white quartz are commonly rejected. The relative abundance of the different minerals varies greatly from place to place.

A partial analysis by Chase Palmer of a specimen of "good ore" from the Jennie mine gave the following composition:

Analysis of ore from the Jennie mine.

SiO_2	43.62
$Al_2O_3(Fe_2O_3)$	3.19
CaO	28.53
Na_2O	.37
K_2O	2.37
CO_2	21.64
	99.72

Mineral composition as calculated from analysis.

Calcite	49.20
Quartz	32.46
Adularia (orthoclase molecule, 13.90; albite molecule, 3.14)	17.04
Excess CO_2	.95

Carbonate was evidently the earliest mineral to form and was later partly replaced by quartz and adularia. On the lowest level of the Jennie mine veins composed largely of carbonate appear to cross the main vein at a low angle and to be later than the quartz-adularia veins, thus indicating two periods of carbonate formation. The exposure, however, did not permit the relative age to be positively determined, and no similar relation was observed elsewhere.

METALLIC MINERALS.

Near Gold Springs and Fay the vein matter contains very little of the metallic minerals. A little pyrite is usually closely associated with wall rock or included fragments of the wall rock, a few copper stains were noted, and gold is frequently visible. In some microscopic sections a light-colored gold, which probably contains considerable silver, is associated with a dark-gray metallic mineral from whose alteration it appears to have been derived. The alteration also yields a cloudy white material, which is usually associated with a little hydrous iron oxide. Sufficient material was not obtained to determine either the original mineral or the cloudy alteration product. It is reported that rich ore from the State Line district shows rather abundant tellurium, and it seems probable that the gray mineral may be a telluride of gold and silver.

In the White Horse claim west of Deer Lodge silver ore contains the chloride of silver, cerargyrite, and that mineral is probably in the other veins of the district. Manganese oxide is present in small amount in most and probably all of the veins of the district. A yellow fibrous mineral collected from the south end of the Jumbo ledge was determined by W. T. Schaller as molybdite. Native mercury is reported from several localities and was panned from material from the Homestake mines. Other metals are reported from the similar veins in the State Line district and from east of Modena and are possibly present in the veins of the Gold Springs district.

In gold and silver content the ores range from those in which the value of the two metals is approximately equal to those in which the value of the silver is much the greater.

ALTERATION.

Most of the wall rock adjacent to the veins has been rather highly altered. This has commonly resulted in a distinct hardening that has rendered it more resistant to weathering and erosion than the surrounding rock and has caused the veins to outcrop as distinct ridges or ledges, many of which stand several feet above the general level.

Mineralogically, the change in the rock shows considerable differences. The most characteristic change is to quartz and orthoclase containing variable amounts of pyrite. Where alteration has been less intense the dark silicates have been chloritized, rather abundant carbonate has developed through the feldspars and the groundmass, and some pyrite has formed. In still other places, probably where the altering conditions have been unusually intense (especially at the south end of the Jumbo vein) the rock has been rather highly sericitized. Kaolinite is present in many places, having apparently resulted from the action of surface waters on the rather highly pyritized wall rock.

The altered wall rock commonly contains but little gold and silver, and such as is present is probably contained in small veinlets rather than disseminated through the rock.

In many places the vein material is tightly "frozen" to the walls of the fissures, but in

some a gouge, due to movement since the formation of the veins, lies along one or both walls and separates the vein material from the wall rock.

ORE SHOOTS.

The veins are not uniformly metalliferous, the ore occurring in distinct shoots. In the Jennie mine these shoots pitch distinctly north, but this does not seem to be uniform throughout the district. Several shoots decrease in size and in metal content with increase of depth, but this also may not be general. In persistency the veins vary greatly, some showing little change and others (including some that are 4 feet wide and are traceable for several hundred feet along the strike), breaking up at a depth of not more than 100 feet into small stringers of quartz in a zone of highly altered rock. The stringers may reunite at greater depth into a definite vein and they may not. In prospecting it is far safer to follow down the ore shoots than to drive long and expensive tunnels to intersect them at depths to which they may not extend as workable deposits. Much money and effort have been fruitlessly expended in the region in this manner, and future prospectors should profit by the experience.

STATE LINE DISTRICT.

No active operations were in progress in the State Line district at the time of the writer's visit, and no opportunity was afforded for examination of the underground workings on the most extensively developed veins.

The veins are in general similar to those in the Gold Springs, Utah, and Fay, Nev., districts to the south but are much less regular. North-trending veins predominate, but some of the most productive trend east. The north-south veins dip prevailingly west at rather steep angles, and the east-west veins dip north. Carbonate is apparently much less plentiful and pyrite much more plentiful than in the veins farther south. Where the fissures have traversed tuffaceous and brecciated areas the alteration of the wall rock has extended for a long distance, producing, especially in the eastern and northern parts of the district, large bodies of resistant rock that form very irregular and rugged outcrops.

As in the districts to the south, the relative amount of gold and silver differs greatly in different deposits. In the Ophir mine, for instance, the value of the ore is almost entirely in silver, and in the Johnny mine the value of the gold is considerably greater than that of silver, though in weight silver considerably predominates.

Exploration in the Ophir mine is said to have been carried to a depth of about 500 feet and in the Johnny mine to about 300 feet, at which level water in considerable amount was encountered. Numerous other deposits in the districts have been prospected and some have produced gold and silver.

The genesis of this type of ores and their distribution in the State are discussed on page 179 and need not be considered here.

The ores occur along a north-south fracture zone several miles in length, which may have been a zone of weakness along which the lavas rose and poured out over the surface. Later recurrent movements along the zone produced fissures through which solutions resulting from the differentiation of deep-seated magmas rose and deposited the vein material and altered the rocks adjacent to the veins.

MODENA AREA.

Some little prospecting has been done near Modena on veins in rhyolite that are in general character similar to those farther north. They contain abundant carbonate which apparently is higher in iron and manganese than that to the north, as the oxidized ores contain these metals in relative abundance and they are said to carry some gold and silver. There has been little if any production from them.

ESCALENTE DISTRICT.

The Escalente district is among the low rolling hills about 12 miles east of Modena. The rocks of the district, which consist of latites and rhyolites with tuffs and breccias, belong to the same series as those of the Gold Springs-State Line districts to the northwest. They are cut by numerous fissures, whose prevailing strike is north to northeast, though one very prominent fissure zone strikes east. The rocks adjacent to the fissures have been hardened and they commonly outcrop prominently, the great east-west fissure forming a conspicuous ridge.

The only fissure that has been extensively prospected (the one worked by the Escalente Mining Co.) is 4 to 10 feet wide, strikes north-

east, and dips steeply southeast. Outcrops can be traced for $1\frac{1}{2}$ to 2 miles but may represent several fissures with the same general strike. Where exposed in the Escalante mines, the walls of the fissure are smooth and well defined.

The veins are of the same general type as those to the northwest but show certain differences, the most pronounced being a smaller amount of carbonate and a greater abundance of base metals. In the specimens examined microscopically fluorite is abundant. Carbonate was deposited in two distinct periods; that formed earlier has been partly replaced by quartz and adularia and that formed later was the last mineral deposited, occurring as a partial filling of cavities along the center of crustified veins. The calcite of the later period may have been deposited by descending solutions and not have been directly connected with the primary deposition of the ore.

The Escalante vein is rather open and porous and had been oxidized to the depth of the development at the time of visit (about 150 feet). The metals so far as observed are all secondary, most of them occurring as incrustations on the cavities in the veins. Oxides of iron and manganese are most abundant. Yellow and green incrustations, which are also abundant, were submitted for determination to W. T. Schaller, who reported as follows:

The abundant yellow coating or stain is descloizite, a lead-zinc vanadate.

The greenish hexagonal crystals are pyromorphite, the chlorophosphate of lead.

The green coating is nickel arsenate, probably annabergite.

The green crystals are arsenate of copper and manganese with a little calcium and uranium (?) and a trace of vanadium.

The form of the silver in the vein was not determined, but in the oxidized zone it is probably the chloride. Assays showing a rather high silver content have been obtained from the prospect, but the average of the vein is rather low, though no definite figures are available.

A little prospecting at one point on the vein, or on a parallel vein, disclosed rather abundant manganese, which is said to contain some silver.

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SMITH, G. H., State Line mining district, Iron County, Utah: Min. and Sci. Press, vol. 84, p. 101, 1902.

IRON SPRINGS DISTRICT.

INTRODUCTION.

The greater part of the following description of the Iron Springs district is abstracted from a report by C. K. Leith and E. C. Harder.[1] The writer (B. S. Butler), however, visited the northern end of the district and has made observations in adjacent sections of the State which lead him to suggest certain interpretations that differ from those set forth by Leith and Harder.

GEOGRAPHY.

The Iron Springs district lies between longitudes 113° 10′ and 113° 26′ 30″ and latitudes 37° 35′ and 37° 47′ 30″ in Iron County, southern Utah, about 250 miles south of Salt Lake City. Lund, on the Los Angeles & Salt Lake Railroad, is 22 miles northwest of the district.

The district lies near the eastern margin of the Basin Range province and includes several basin ranges and hills, principal among which are the Harmony Mountains, Iron Mountain, Antelope Range, Granite Mountain, The Three Peaks, and the Swett Hills. To the south are the Pine Valley Mountains. Immediately west, north, and east of the district lies the desert, beyond which on the west and north are other basin ranges, and on the east, 12 miles away, is the Hurricane fault scarp of the High Plateaus. On the southwest the district is continuous, with a series of ranges and hills extending west of the Pine Valley Mountains well into Nevada. The elevation ranges from 5,300 to 8,000 feet.

The drainage is through small creeks that lose themselves in the desert a short distance from the mountains.

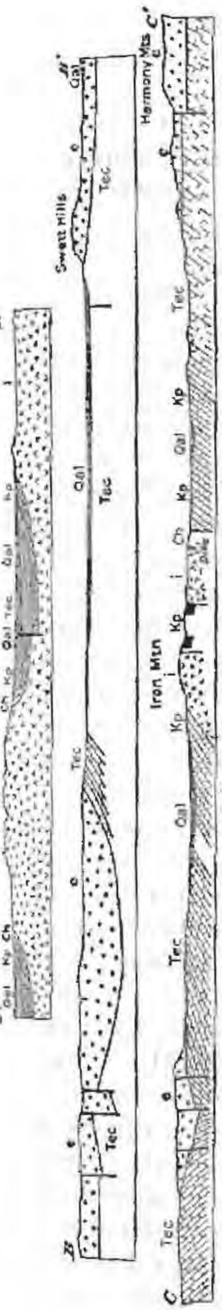
The tops of the Harmony Mountains retain snow until the middle of summer, and consequently have an abundance of vegetation, such as yellow pine, fir, cottonwood, quaking aspen, and mountain mahogany. The tops and slopes of the other mountains are dry and are covered with a growth of scrub cedar and piñon.

GEOLOGY.

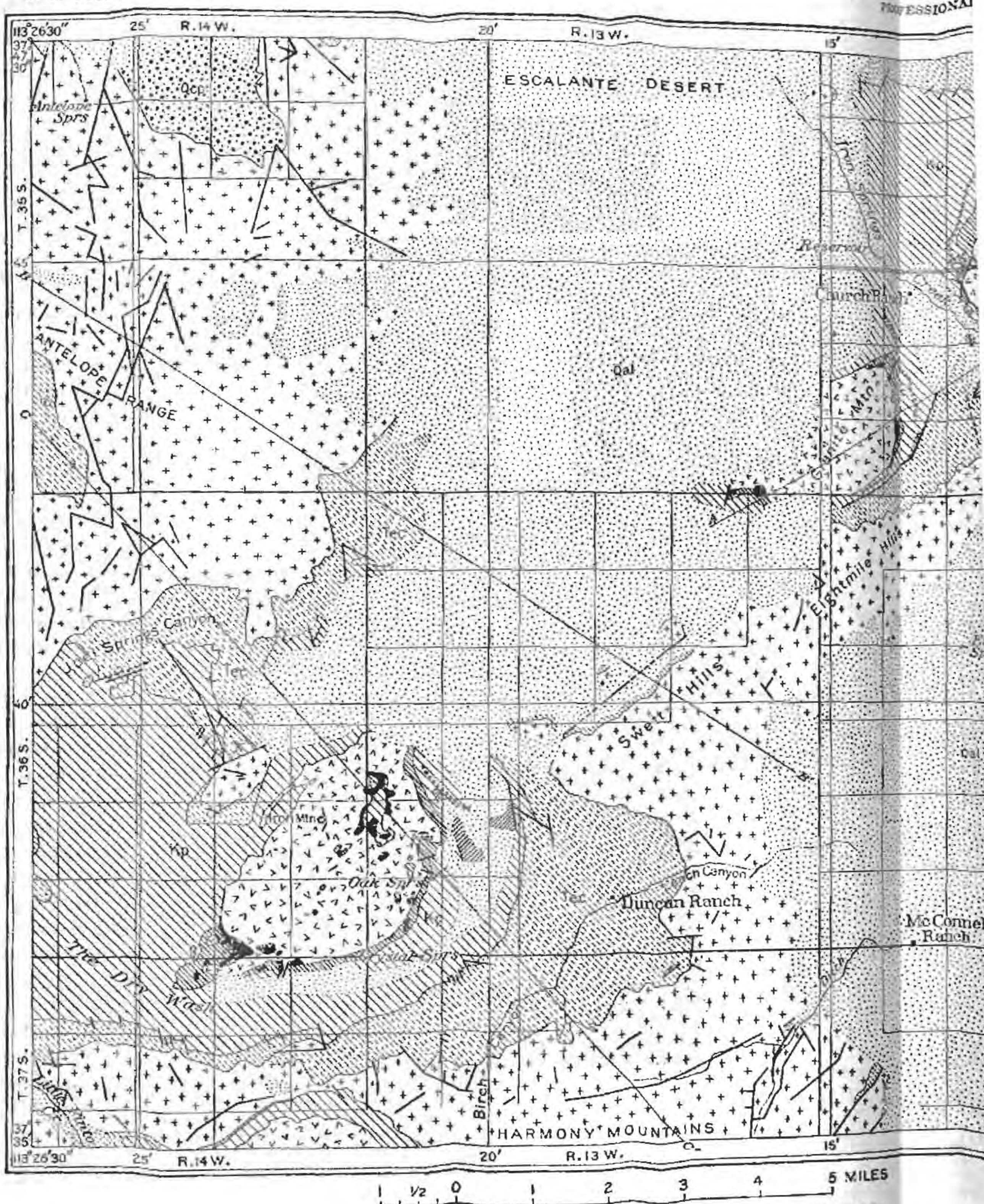
GENERAL FEATURES.

The dominating geologic features of the district are three large laccoliths, constituting the Three Peaks, Granite Mountain, and Iron Mountain, which lie northeast and south-

[1] The iron ores of the Iron Springs district, southern Utah: U. S. Geol. Survey Bull. 338, 1908.

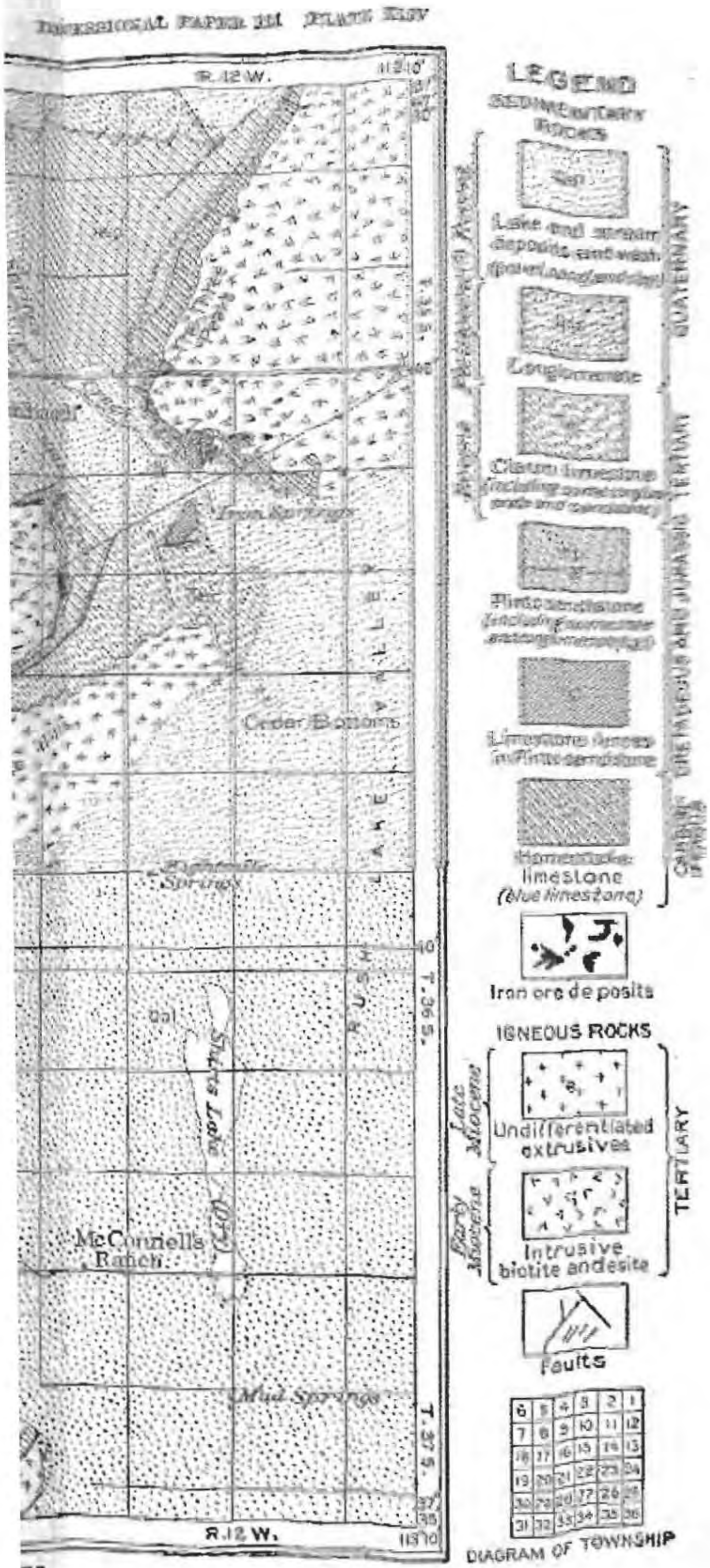


SECTIONS ALONG LINES A-A', B-B', AND C-C'



GENERALIZED GEOLOGIC MAP AND SECTIONS OF IRON SPRINGS DISTRICT.

Drawn from map by Leith and Harder.



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west across the district. (See Pl. XLIV.) Three unconformable sedimentary series, aggregating 4,000 feet in thickness, outcrop in successive rings around these laccoliths and dip outward asymmetrically, very steeply at the contact, less steeply farther away. Still farther from the laccoliths nearly horizontal lava flows 2,000 feet thick lie on the tilted sedimentary rocks. These general relations are modified by faulting.

STRATIGRAPHY.

All the rock formations of the district are more or less covered on the middle and lower slopes by unconsolidated and partly consolidated erosion débris, both aqueous and subaerial, which spreads out on the lower ground to make the deserts. The detailed succession is shown in figure 62.

The laccoliths,[1] whose upper parts only are exposed, consist of andesite of remarkably uniform texture and composition. Within their area are a few veins of iron ore, fault blocks of ore, and Carboniferous and Cretaceous sediments.

In contact with the laccoliths for the most part is Carboniferous limestone, a pure, dense, blue limestone, with a few feet of sandy material appearing locally at the base. The contacts are at most localities nearly vertical, this being due partly to faulting and partly to the fact that erosion has cut down far enough to expose the vertical sides of the laccoliths. Locally, where erosion has not cut so far, the limestone dips distinctly away from the andesite at an angle as low as 10°. The limestone is altered at the contact to a maximum distance of 1,000 feet, as measured on the erosion slopes, by loss of carbonates, development of anhydrous silicates, and replacement by ore.

Cretaceous sediments outcrop in a zone outside of the Carboniferous limestone, except where locally they are faulted down against the laccolith, or where the laccolith has penetrated the Cretaceous and erosion has not yet cut down to the Carboniferous limestone, as on the west side of Iron Mountain. The Cretaceous rocks are principally sandstone, with layers or lenses of shale, conglomerate, and limestone breccia. At the contact with the laccoliths the sandstone has been indurated and amphibole has developed.

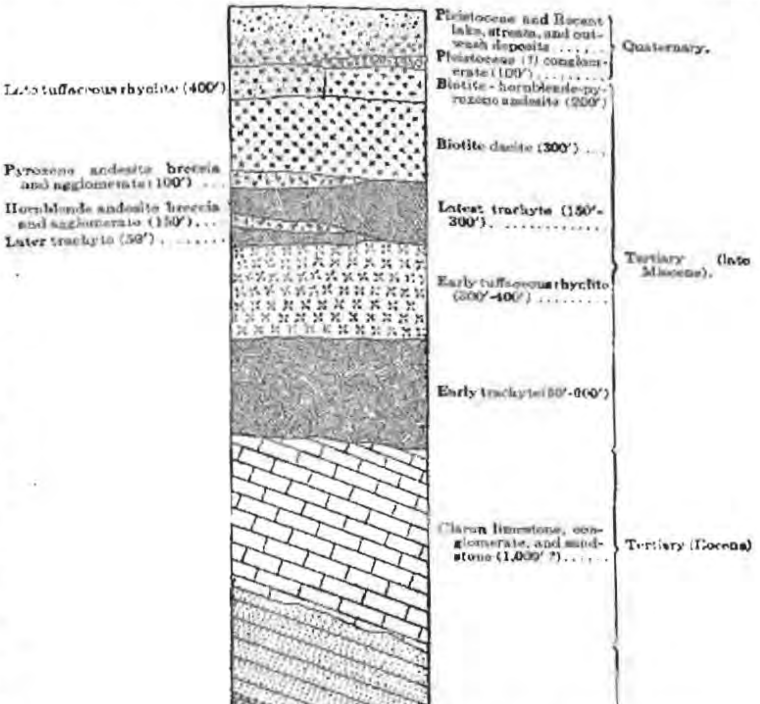

FIGURE 62.—Geologic column of the Iron Springs district.

The relations of the Cretaceous sandstone to the underlying Carboniferous limestone are those of apparent conformity, but the contact is rendered somewhat obscure by the presence of shale at the base of the Cretaceous sandstone. The lower portion may be in part Jurassic, but separation could not be made. The greatly varying thickness of the Carboniferous limestone may be due partly to erosion and partly to intrusion of andesite at different horizons. If it represents erosion, it shows unconformity. Notwithstanding the conformity

[1] That these are laccolithic bodies has not been demonstrated and the writer is inclined to regard them as stocks.

of structure, it is not unlikely that there may be a hiatus between the two systems, for the correlation of the two is fairly well based, and the Permian, Triassic, and some Jurassic sediments are lacking between them.

The Eocene series outcrops in a zone still farther away from the laccoliths. It consists of limestone and conglomerate, characterized principally by pink and bright-red colors and separated by a basal conglomerate from the Cretaceous sediments below. Its dip averages about the same as that of the Cretaceous, from which it is separated by a marked erosion unconformity.

Miocene lavas and tuffs rest nearly horizontally upon the eroded edges of the Eocene sediments and to a less extent upon the Cretaceous.

In the northwestern part of the area, near Antelope Springs, a Pliocene or Pleistocene fluviatile deposit, principally a conglomerate containing fragments of lavas of the earlier andesite laccolith, and of the sediments, occupies an embayment in the lavas.

Pleistocene and Recent lake, stream, and outwash deposits, consisting of gravels, sands, and clays derived by erosion from all of the rocks of the district, occupy nearly half of the area and mask the rock formations of the lower ground.

STRUCTURE.

Fault scarps are common, and streams or canyons prevailingly follow faults and joints, especially the former. The larger and more conspicuous faults trend prevailingly north, but others follow other directions. At several localities, especially near the ore deposits, the faults tend to follow the periphery of the andesite laccoliths.

The fault planes are vertical, or nearly so. The displacements range from vertical to horizontal but are chiefly vertical in the faults mapped. The maximum vertical displacement known is 2,000 feet; the maximum horizontal displacement is unknown. Hinge faults, the displacement at one end of which is opposite to that at the other, were found locally in the lava area. Probably many faults with a displacement parallel to the dip of the beds have not been detected. Allowing for a considerable unknown horizontal component of displacement, there remains a probable dominance of vertical movement sufficient to indicate that the net result of the faulting has been the extension of the area; in other words, the faults are primarily tension phenomena.

Conspicuous in the andesite are fissures, some of them filled with ore, which curve, taper, branch, and parallel themselves in such a manner as to suggest that they are stretch fractures. In the andesite area on Three Peaks a conspicuous parallel fracturing is spaced at intervals of a fraction of an inch for several feet. In the neighborhood of ore veins the fissures trend parallel to the veins.

The faults and other fractures are believed to be due principally to the successive extension, shortening, and settling that accompanied the intrusion and the cooling of the laccoliths, as cited by Spurr for some of the faults of the Tonopah district. The faults are tension phenomena and are so numerous and so intricate in their intersections that it is easier to explain them by somewhat local strains accompanying cooling than by strain on the rocks of the district as a whole. The faults outlining the periphery of the andesite and the stretch fractures within the andesite may be ascribed definitely to this cause. A rough calculation of the cubic shrinkage of a mass of andesite the size of the Iron Mountain laccolith in crystallizing from a glass to andesite indicates a horizontal radial shortening of 200 to 500 feet (according to the depth assumed for the mass), a large enough factor to be important in the development of fractures.

So far as the faulting was due to the intrusion and cooling of the andesite, it followed the intrusion closely and is of Tertiary age. Other faults cut the lava flows and are therefore considerably later than the laccolith intrusions. These faults are, from their nature, probably in part due to the cooling of the lavas.

Certain of the larger faults, especially those trending north and showing great extent and continuity across both igneous and sedimentary formations, may be due to other causes than cooling. They seem to belong more to the order of deformation producing the Hurricane fault to the east than to the deformation associated with local igneous action. The whole Iron Springs district represents a downthrow on the west side of the Hurricane fault. The stresses have affected large areas. There can be little doubt that these great faults are essentially tensional in nature, but the cause of the tension is not clear.

GEOLOGIC HISTORY.

The principal events in the geologic and physiographic development of the district have been in order as follows:

(1) Deposition of Carboniferous limestone, with thin fragmental base, on unknown basement.

(2) Nondeposition, perhaps erosion, followed by deposition of Cretaceous and perhaps of some Jurassic sandstone with layers of shale, conglomerate, and limestone.

(3) Erosion, followed by deposition of Eocene limestone and conglomerate in an inclosed basin. Shallow water, strong currents, and rapid changes obtained through both Cretaceous and Tertiary time.

(4) Intrusion, in early Miocene time, of andesite laccoliths, principally into the Carboniferous limestone but also into the overlying Cretaceous, accompanied by tilting of all the formations away from the laccoliths, steeply near the laccoliths, less steeply farther away. Metamorphism of limestone and sandstone near the contact.

(5) Fissuring and faulting caused by cooling of laccoliths.

(6) Advent of ore-depositing solutions through fissures in the andesite, depositing iron ore in the andesite fissures and in the adjacent limestone and altering the wall rock.

(7) Erosion, exposing the laccoliths and rings of sediments and ores around them.

(8) Extrusion of late Miocene lavas over the entire area, except possibly some of the higher peaks of the exposed laccoliths, effecting a secondary concentration of the ores and further altering the underlying rocks.

(9) Further faulting.

(10) Vigorous erosion, reexhuming the andesite cores and developing the Pleistocene conglomerate and the Pleistocene and Recent mantle of stream, lake, and other alluvial deposits.

Several of the intrusive bodies in central and southern Utah, and particularly in the Tintic, Frisco, and Marysvale regions, where both the extrusive and intrusive rocks are very similar to those at Iron Springs, are known to be later than the associated extrusive rocks; and from observations in the northern part of the district and from a study of the map accompanying Leith and Harder's report, the writer suggests that in the Iron Springs district also the extrusive rocks are perhaps earlier than the intrusive. His reasons are as follows:

The extrusive rocks through nearly their entire extent rest upon the Tertiary sediments. At a few localities they are represented on the map as in contact with Cretaceous rocks, but nowhere are they in contact with the Carboniferous sediments or with the intrusive rocks. If they had flowed over a mature erosion surface in which all these rocks were exposed, one would expect that somewhere they would be in contact with the earlier rocks, especially because the lavas are nearly as resistant to weathering and erosion as the intrusive rocks and are far more resistant than the sedimentary rocks. In general also they dip away from the intrusive bodies as much as would be expected considering their distance from them.

The lavas may have been poured out on a surface of Tertiary rocks (with possibly some exposures of Cretaceous rocks) which was subsequently lifted by the igneous intrusive into a broad anticline with subsidiary domes at points where the intrusive was greatest. This anticline, rising above the general elevation, was vigorously attacked by erosion, which eventually removed all the rocks above the intrusive body and left the several formations outcropping about it in concentric bands regardless of their degree of resistance to erosion.

Leith and Harder designate three principal periods in the development of the topography: (1) Intrusion of laccoliths in early Miocene time, followed by faulting and erosion exposing the laccoliths and surrounding belts of sediments and developing in the laccolith cores a mature type of topography; (2) extrusion of late Miocene lavas, followed by faulting and by erosional exhumation of the laccolith cores and surrounding sediments, so far as they had been covered by the lavas; and development of a mature type of topography in the lavas themselves; (3) development of the hurricane fault to the east, causing a slight renewal of activity, exhibited in the sharp canyons and steep sides of some of the lava hills.

They note that, according to Huntington and Goldthwait, their earliest period is not recognized in the Toquerville district to the southeast. If it should prove that the intrusions in the Iron Springs district were later than the extrusions, this earlier erosion period would be eliminated and the sequence of events in the two districts would be in essential harmony.

SEDIMENTARY FORMATIONS.

CARBONIFEROUS SYSTEM.

HOMESTAKE LIMESTONE.

Distribution and character.—The Homestake limestone outcrops in or around the andesite laccolith areas in contact with the andesite.

West of the Three Peaks laccolith it is exposed in a band extending from the northern boundary of the district southwestward for about 3 miles and then southeastward to a point northeast of Iron Springs, except for about a mile, where the Cretaceous formations are faulted into contact with the andesite.

Northeast of the Granite Mountain laccolith a band of Homestake limestone is exposed for about 2 miles. Both ends of this band are overlapped by the Pinto sandstone, which here again comes in contact with the andesite. At the Desert Mound, southwest of Granite Mountain, the Homestake limestone again appears. It is cut off by a fault on the west and disappears under the lake and stream deposits on the east.

The Iron Mountain laccolith is bordered by the Homestake limestone on its northeast, east, south, and southwest sides, with a few interruptions due to faulting or covering by surface deposits. Southwest of the laccolith the outcrop of the limestone is rather wide, owing to the fact that the surface of the supporting laccolith is nearly horizontal here, as shown by the tongue of andesite extending westward from the main mass and by the few andesite outliers in the Homestake limestone. On the west and north sides of the Iron Mountain laccolith, as in Granite Mountain, the Homestake limestone is not exposed, the Cretaceous sandstones lapping against the laccolith.

A patch of Homestake limestone is present in the Comstock iron deposit in the Cretaceous area southwest of the Homestake mine; others are scattered irregularly within the area of the Iron Mountain laccolith.

The Homestake limestone is a dark bluish-gray limestone of dense texture, with uniform characteristics throughout its entire extent, except near the laccolith contact. Under the microscope it appears to be made up of exceedingly minute grains of calcite with scattered grains of pyrite, magnetite, and chert.

The bedding of the Homestake limestone is very indefinite, and is easily confused with secondary fracturing. Where well defined the limestone is generally thin bedded.

Many of the altered contact phases of limestone are hard to distinguish from a much-fractured quartzite or clayey sandstone which is locally exposed below the limestone and constitutes a part of the same formation. The sandstone lies between the ore deposits and the andesite, or between the ore and the limestone. It is conspicuous also in the limestone patches faulted into the andesite.

The thickness of the Homestake limestone, as shown by exposures, ranges from 50 to 500 feet. The average thickness has been taken to be about 200 feet. The variation is probably due to intrusion of laccoliths at different horizons. If the intrusion has followed the base, the variation in thickness may indicate unconformity with the overlying Pinto sandstone.

Contact metamorphism.—The limestone adjacent to the andesite has been locally replaced by iron ore and has been generally vitrified, silicated, and kaolinized in a band usually not more than 60 feet wide along the erosion surface but locally a few hundred yards wide where the erosion surface is nearly parallel to the limestone-andesite contact. Locally either or both contact phases are absent.

The altered limestone is a grayish, yellow, or greenish, fine-grained, argillaceous-looking rock. Near the contact it is soft, and farther away it is hard and fractured into small irregular blocks. The principal minerals are albite, kaolin, actinolite, diopside, quartz, orthoclase, serpentine, phlogopite, andradite, iron ores, osteolite, andalusite, wollastonite, and calcite, varying greatly in proportion in different places but usually occurring in quantity in the order named. They are found in veins, in breccias, and disseminated through the rock. In addition, there are local residues of a glassy base.

Another phase is coarsely crystallized limonite-stained marble, in some places found in a narrow belt between the andesite and the normal silicated contact phase and elsewhere outside of the normal phase or associated with the ore. It is thought possible that this limonitic marble is a later material, filling openings along the contact left by the cooling and crystallization of the intrusive and intruded masses.

Analyses of various phases of the Homestake limestone are given on page 171.

As a result of consideration and calculation of the analyses, Leith and Harder arrive at the following general conclusions concerning the changes that have taken place:

It is concluded that in general there has been large loss of material from the limestones at the contact without conspicuous introduction of new material except soda, but that exceptional phases show clearly the introduction of silica and iron. Both normal and exceptional phases of the contact rocks are cut by later veins of calcite and iron ore, with associated minerals similar to those of the limestone contact.

A consideration of the density and volume changes leads the authors to the conclusion that there has been a pronounced shrinkage of the limestone during metamorphism. They sum it up as follows:

If the principal chemical change in the development of the contact phase has consisted in the elimination of calcite and to a less extent of magnesia, iron, and potassa, leaving alumina and silica substantially unchanged in their ratios, this has involved a very considerable loss of weight, and, as the densities of the fresh and altered rocks differ so little, the loss in volume also has been large. Kemp,[1] Lindgren,[2] and others have cited lack of structural evidence of diminution in volume at limestone contacts as favoring the view that materials must have been introduced from without to take the place of the calcium carbonate. Kemp[3] in a review of Bulletin 338, dissents from the conclusions concerning the additions during metamorphism; Lindgren[4] expresses a similar opinion. In the Iron Springs district the field evidence does not positively prove or disprove important volume change, but there is no apparent field evidence to contradict the evidence for diminution of volume here calculated. The limestone, though tilted away from the andesite laccoliths, nowhere shows evidence of crumpling or crowding where the bedding can be observed. In the altered phase the bedding has been destroyed, and it is easy to conceive that this structurally amorphous zone may represent only a part of the volume of the original rock, the calcium carbonate having been driven off and the other constituents concentrated. The change in volume of the limestone would scarcely be expected to stand out conspicuously in the field relations, for it has occurred, if at all, in the band which now does not show original textures or structures, by which change of volume can be measured in crumpling or folding. In general it appears that there may have been important diminution of volume, accomplished essentially by loss of materials and not by change of density of minerals.

Observations in the northern part of the field failed to reveal to the writer evidence that the contact metamorphism in this district is essentially different from that in other districts of the State, where, it is believed, additions of magmatic material have been extensive.

[1] Kemp, J. F., Ore deposits at the contacts of intrusive rocks and limestones and their significance as regards the general formation of veins: Econ. Geology, vol. 2, pp. 1-13, 1907.

[2] Lindgren, Waldemar, The copper deposits of the Clifton-Morenci district, Ariz.: U. S. Geol. Survey Prof. Paper 43, 375 pp., 1905.

[3] Kemp, J. F.; Econ. Geology, vol. 4, pp. 782, 791.

[4] Mineral deposits, p. 670, New York, McGraw-Hill Book Co., 1913.

Introduction of ore.—The introduction of ore took place after the development of the silicated contact phase, as is demonstrated by its occurrence in fissures that intersect this phase. The silicated contact phase is found also along parts of the contact where ore is absent. The introduction of ore-bearing solutions effected further metamorphism of the limestone of approximately the same sort, nearly all of the minerals found at the barren contacts being duplicated within and adjacent to the ore itself. Apatite, amphibole, biotite, pyrite, and garnet are more abundant in association with the ores than elsewhere in the contact phase, and albite and orthoclase appear in the contact phase and not in the ores. Beyond this it has not been found possible to separate the metamorphic effect of the ore-bearing solutions, aside from its deposition of ore, from the earlier contact effect of the andesite, although it is thought likely that additional careful field work might discover further criteria for their separation.

CRETACEOUS SYSTEM (PERHAPS IN PART JURASSIC).

PINTO SANDSTONE.

The composition of the Pinto sandstone, which conformably overlies the Homestake limestone, varies somewhat in different parts of the district. A generalized section in the northeastern part of the district follows.

Generalized section of Pinto sandstone in Granite Mountain and Three Peaks areas.

	Feet.
Sandstone, yellowish brown and gray	1,000+
Conglomerate, with interbedded sandstone	20-40
Sandstone and shale, variegated	40-75
Conglomerate	8
Cherty limestone breccia	10-20
Sandstone, maroon and spotted	40-60
Shale, purple and green	30-50

TERTIARY SYSTEM (EOCENE SERIES).

CLARON LIMESTONE.

The Claron limestone unconformably overlies the Pinto sandstone. It consists mainly of limestone, with a few thin layers of conglomerate and a few heavy beds of sandstone, and of a basal conglomerate 2 to 25 feet thick.

Adjacent to the lavas the limestone has been metamorphosed to white, gray, or red chert, chalcedony, and moss agate or jasper throughout a maximum thickness of 15 feet. The red moss agates and jaspers are colored with iron. A white powdery calcium carbonate, apparently deposited by hot springs, and especially abundant north of Eightmile Hills, is asso-

ciated with many of these cryptocrystalline varieties of quartz and with many ore deposits.

At Chloride Canyon and elsewhere, near the contact with the lavas, the limestone contains veins carrying calcite, barite, and quartz, and subordinate amounts of galena, pyrite, chalcopyrite, siderite, limonite, magnetite, and copper carbonates. Gold and silver are reported, the silver probably being contained in the galena. Similar mineral veins are found in the Homestake limestone, both associated with and remote from iron-ore deposits.

QUATERNARY SYSTEM.

Pleistocene and Recent conglomerates, sandstones, and clays are present over much of the lower areas of the district.

IGNEOUS ROCKS.

The igneous rocks of the district are both intrusive and extrusive. Biotite andesite laccoliths were intruded into the Paleozoic and to a less extent into the Mesozoic rocks after the deposition of the Tertiary sediments. Later a bedded series 1,000 to 2,000 feet in thickness, consisting of rhyolitic, trachytic, and andesitic flows, tuffs, and breccias, was extruded.

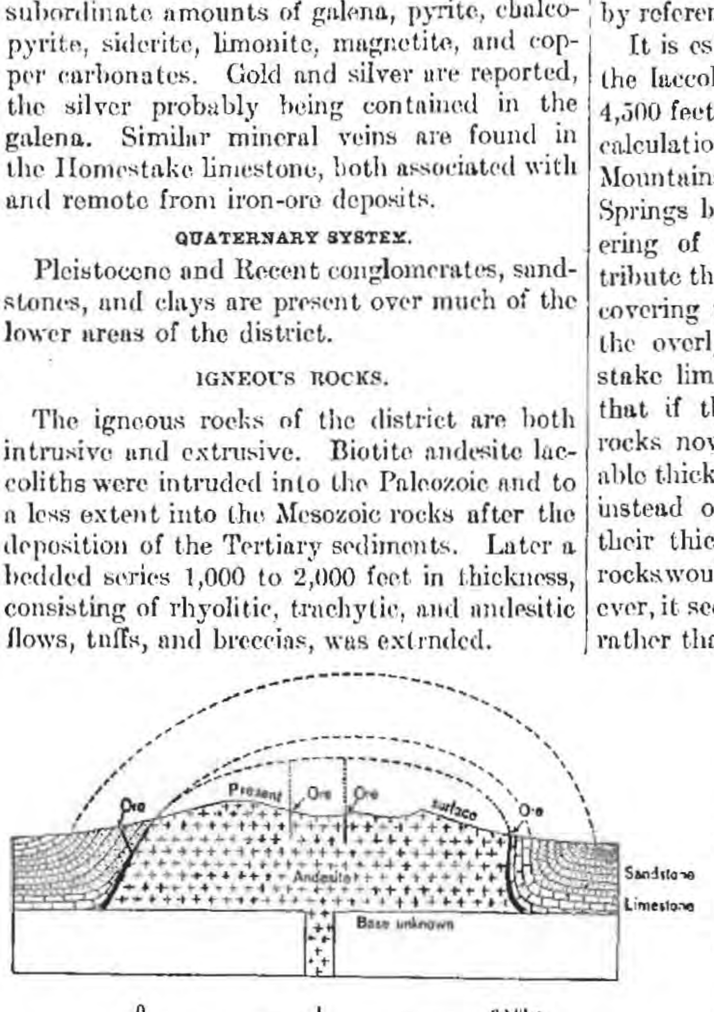

FIGURE 63.—Ideal cross section through the Iron Mountain laccolith, showing structural relations of ore.

The lavas rest on the eroded and upturned edges of the Eocene and Cretaceous sediments, indicating that a considerable period of erosion intervened between the intrusion of the biotite andesite and the outpouring of the extrusive rocks. They have been correlated with the Miocene lavas of the Wasatch Mountains, and hence the andesite intrusion is post-Eocene and probably early Miocene.

Quaternary basalts surround the Iron Springs district but do not occur within it.

LACCOLITHS (EARLY MIOCENE).

DISTRIBUTION AND STRUCTURE.

The laccoliths form the cores of the three principal mountain groups of the district—the Three Peaks, the Granite Mountain, and the Iron Mountain—and also the core of a fourth, Stoddard Mountain, which lies mainly southwest of the area mapped. The size and form of the laccolithic bodies can be best understood by reference to figure 63.

It is estimated that at the time of intrusion the laccoliths were covered by approximately 4,500 feet of sedimentary rocks. According to calculations made by Gilbert for the Henry Mountains, laccoliths of the size of the Iron Springs bodies would require a minimum covering of 7,000 feet. Leith and Harder attribute the greater efficiency of the Iron Springs covering to greater strength and resistance in the overlying sediments, notably the Homestake limestone. It may be noted, however, that if the 1,000 to 2,000 feet of extrusive rocks now exposed, and probably a considerable thickness that has been removed, are older instead of younger than the intrusive rocks, their thickness added to that of sedimentary rocks would satisfy Gilbert's calculations. However, it seems likely that these bodies are stocks rather than laccoliths.

PETROGRAPHY.

The intrusive andesite[1] is the rock with which the iron-ore deposits are associated. Deposits are found on the borders of all the andesite areas except Stoddard Mountain (outside the Iron Springs district), where its absence is probably due to the absence of limestone.

The rock is a light-gray biotite andesite with porphyritic texture. The phenocrysts, consisting of feldspar, biotite, hornblende, and diopside are numerous, occupying more than half of the rock mass and reaching a maximum diameter of an eighth of an inch. The most abundant phenocrysts are plagioclase (labradorite), but some of orthoclase are present. A large number of feldspars show zonal growth. They are comparatively fresh, showing alteration only along cracks, along lines of zonal growth, and on the surface. The alteration products are calcite, kaolin, quartz, and sericite, typical katamorphic products. The next most abundant phenocryst is biotite, in shiny black hexagonal plates, in many places altered to phlogopite with a golden luster and with reaction rims of magnet-

[1] To rocks of this general character in other districts the name of monzonite porphyry has commonly been applied.

ite. In the Stoddard Mountain area and parts of the other areas the biotite is almost entirely decomposed to ferrite. In a few places it has altered to green chlorite. The biotite has abundant inclusions, mainly apatite, but in places quartz, magnetite, and zircon. The hornblende is generally in dark-green prismatic crystals, with inclusions of magnetite, biotite, and quartz. Like the biotite the hornblende in the andesite of the Stoddard Mountain area is almost entirely decomposed to ferrite. The diopside is light green and is noticeably associated with magnetite, which forms inclusions and surrounds borders. It is generally more or less altered to uralite along cracks and around the border. Fragments of magnetite are abundant. Ferrite is present as an alteration product of the ferrous silicates.

The groundmass is cloudy from alteration but seems to be composed mainly of fine crystalline quartz and feldspar, both orthoclase and plagioclase. Biotite, hornblende, pyroxene, and magnetite are also represented, but less abundantly.

The biotite andesite has the same texture and mineral composition throughout the different areas. The absence of marginal facies (as a basic edge), dikes, and pegmatitic veins is especially noticeable.

METAMORPHISM.

For a few feet near its contact with the ores the andesite has a greenish-yellow color and dense texture, very similar to that of the silicated limestone at the andesite contact. The two are with great difficulty discriminated. The grain of the contact phase is much finer than that of the main mass of the andesite. The groundmass consists of finely crystalline feldspar and quartz (principally feldspar) and is cloudy with dark clayey-looking material, much of which is not recognizable, but some of which is clearly muscovite and rarely chlorite. The contact between the altered phase and the fresh andesite is sharp.

A comparison of the analyses of the fresh and contact phases brings out clearly the conspicuous introduction of soda. All other constituents show a possible loss, though ferric iron has developed at the expense of ferrous iron. At present specimens from horizons surely below the influence of weathering can not be obtained, and the oxidation of the ferrous iron may really be a superposed weathering effect.

Analyses of fresh and altered andesites.

[Analyst, R. D. Hall, University of Wisconsin.]

	A	B	C	D	E
SiO_2	65.29	63.63	65.80	63.82	63.76
Al_2O_3	11.57	15.64	14.48	14.28	16.05
Fe_2O_3	2.10	3.59	3.96	2.72	1.91
FeO	2.67	.93	.70	.81	.58
MgO	2.87	2.32	2.35	5.98	2.46
CaO	4.85	4.46	3.19	.70	4.25
Na_2O	2.10	1.70	3.78	3.62	6.26
K_2O	5.18	5.22	3.32	4.24	2.84
H_2O-	.50	.40	.12	2.30	1.22
H_2O+	1.82	1.70	2.71	1.68	.93
P_2O_5	.22	.15	.12	.04	.28
BaO	.17	.05	.06	.04	None.
	99.34	99.79	100.59	100.23	100.54

A. Specimen 46612. Fresh andesite east of Granite Mountains.
B. Specimen 46377. Weathered andesite from Desert Mound.
C. Specimen 45433. Altered andesite near iron-ore contact from Blowout, south of Iron Mountain.
D. Same nearer iron-ore contact.
E. Specimen 46481. Altered andesite near iron-ore contact from Emma claim on east slope of Iron Mountain.

When the normal weathered andesite from the surface is compared with the fresh andesite the change is found to be very different from that along the ore contacts. All constituents, including soda, show a loss relative to the alumina.

EXTRUSIVE ROCKS (LATE MIOCENE).

The extrusive rocks occupy two main areas in the district—the Antelope Range area and the Swett Hills, Eightmile Hills, and Harmony Mountains area. There are small exposures at Upper Point, in the northeastern quarter, and northwest of Iron Mountain.

There is a succession of 9 flows in the following order:

Succession of lava flows in Iron Springs district.

	Feet.
9. Biotite-hornblende-pyroxene andesite	200
8. Late tuffaceous rhyolite (Antelope Range)	400
7. Biotite dacite	300
6. Pyroxene andesite agglomerate and breccia	100
5. Latest trachyte	150–300
4. Hornblende andesite breccia and agglomerate	150
3. Later trachyte	50
2. Early tuffaceous rhyolite	300–400
1. Early trachyte	50–600

Of these Nos. 1, 2, 5, and 7 extend throughout the area and for a number of miles to the south and west, but the rest are present only in parts of the district. There is little evidence of erosion between the successive flows, unless the absence of certain beds in different places may be taken as such. The border of the lava series is the oldest formation, and inside of this

successively younger flows outcrop, the latest in the center. Local faulting and sheets of outwash deposits have somewhat obscured these relations in places.

The Antelope Range lavas occupy a broad syncline pitching to the northeast, while those of the Swett Hills and Harmony Mountains have a general eastward dip and are not folded.

CHEMICAL AND MINERAL COMPOSITION.

Analyses have been made of the intrusive andesite and of the four principal flows, namely, the early trachyte (1), early rhyolite (2), latest trachyte (5), and dacite (7). Of the rest of the flows, some, though they have considerable horizontal distribution, are very thin, and the others are local in their distribution.

The following table shows an approximation of the average chemical composition of the lavas and andesite, obtained by averaging the analyses. The general similarity of composition indicates that both may have come from the same reservoir.

Average chemical composition of laccoliths and extrusive rocks.

	Laccoliths.	Extrusive rocks.
SiO_2	64.46	66.42
Al_2O_3	13.60	15.41
Fe_2O_3	2.85	3.48
FeO	1.80	.96
MgO	2.59	1.34
CaO	4.65	3.40
Na_2O	1.90	1.86
K_2O	5.20	5.99
H_2O+	2.21	.95
P_2O_5	.18	.19
BaO	.11	.09
	99.55	100.09

SOURCE.

The question naturally arises whether the intrusive and the extrusive rocks came from the same reservoir. The chemical composition of the laccolithic rocks and of the different flows show small range. With very little differentiation all the different phases may have originated from the same parent magma. It is certain, however, that the laccoliths did not act as vents through which the lavas were outpoured. The andesite had been intruded, solidified, and eroded when the lavas were poured out over the eroded edges of the uplifted sediments. That the lavas came to the surface through the laccoliths after their solidification and erosion does not seem likely, for the andesite areas show no dikes or stocks, unless the ore veins be so called. Neither are there stocks or dikes elsewhere in the district through which the eruptions might have occurred; hence we are driven outside of the area for the source of the extrusive rocks.

HISTORY AND PRODUCTION.

By V. C. Heikes.

The Iron Springs district includes two mining districts—the Iron Springs, in the northern part of the area, and the Pinto Iron, in the southern part.

Iron Springs district.—The Iron Springs district, in Iron County, 22 miles south-southeast of Lund, on the Los Angeles & Salt Lake Railroad, was first organized in 1871, and was reorganized on March 27, 1879. About 1856, at Cedar City, 8 miles east of Lund, considerable iron ore was reduced with fair success in an imperfect furnace.

Pinto district.—The Pinto iron district, organized May 26, 1868, is in Iron County, a few miles southwest of the Iron Springs district, 20 miles west of Cedar City, and 32 miles southeast of Modena, the nearest station, on the Los Angeles & Salt Lake Railroad. Huntley[1] gives the following description of the district:

> There were [July, 1880] 23 iron claims, 1,500 by 600 feet each, in an area 1 mile wide and 4 miles long, beginning 3 miles northeast of the town. * * *
>
> In 1868 the Great Western Milling & Mining Co. was organized by five Mormons. A rude furnace, a foundry, * * * were erected. * * * In 1875 or 1876 the works were shut down. * * * The company made only four runs, in all about nine months, and produced 400 tons of pig iron. This was made into castings, principally shoes and dies for the mills at Pioche, and was considered of excellent quality. The company expended about $100,000. * * *
>
> The old Silver Belt district was included in the Pinto district. The former was cut off in 1873, and joined again in 1875. It is located north of Pinto district, and contained at the time of the writer's visit 60 locations. The ore is quartzite, with some copper stain and lead, and assays from $40 to $60 silver per ton. The veins are from 2 to 4 feet wide.

In 1912 a trial shipment of lead ore containing a little silver was made from the Homestake claim.

IRON-ORE DEPOSITS.[2]

OCCURRENCE.

The iron ore occurs in disconnected masses within a general northeast-southwest area about 1½ miles wide by 20 miles long (see Pl. XLIV) lying for the most part on the eastern and southern slopes or foothills of the Three Peaks, Granite Mountain, and Iron Mountain. Most

[1] Precious metals: Tenth Census U. S., vol. 13, pp. 476-477, 1885.
[2] Abstracted from Leith, C. K., and Harder, E. C., op. cit., pp. 66-86.

A. VIEW SHOWING SOUTHERN CROSS IRON-ORE DEPOSIT, EAST OF GRANITE MOUNTAIN, LOOKING NORTH.

The ore forms the summit and the dark area on the slope to the right and foreground; the light area to the west is footwall andesite; hanging-wall sediments occupy the lower half of the slope to the right.

of them are at elevations of 5,600 to 6,700 feet, but some, as on Iron Mountain, are at or near the tops of the mountains at elevations between 7,000 and 8,000 feet.

Some of the iron-ore exposures rise 200 feet above the surrounding country as black, jagged ridges. (See Pl. XLIV, *B*.) Others, including several of the larger deposits on the lower slopes, are recognized only by isolated exposures and by black iron-formation fragments disseminated in loose detrital material. Some of the ore does not outcrop at all, being covered by andesite detritus washed from the upper slopes, though even here fragments of ore are likely to appear farther down the slopes. In such places the exact shape and distribution of the deposits can not be determined without trenching or pitting. Fortunately such work will suffice fairly well throughout the possible ore-bearing areas, though there are places where areal extensions of iron-ore belts may be found by underground exploration, or where belts, mapped as continuous on the basis of surface fragments, may really be discontinuous. The deepest pits in the district, 130 feet, have not yet reached water level.

GEOLOGIC AND STRUCTURAL RELATIONS.

The ore deposits for the most part lie at or near the contact of the andesite laccoliths and the Homestake limestone. Some of them are entirely within the andesite well up the slopes, and others are entirely within the limestone, though few of these are far from the contact. (See fig. 63.)

EPOSITS IN ANDESITE.

The deposits within the andesite appear at the surface in long, narrow bands from 20 feet to less than 1 foot in width, standing from a few feet to 30 feet above the adjacent andesite. These are true veins or fissure deposits. Most of the fissures which they fill are somewhat curved, taper at one or both ends, almost invariably branch, and are accompanied by subsidiary parallel fissures. Their orientation is diverse; in general they follow the directions of the adjacent jointing and faulting.

DEPOSITS AT ANDESITE-LIMESTONE CONTACT.

The larger and more numerous deposits are along the andesite-limestone contact. (See Pl. XLV, *A*.) The outcrops are commonly lens-shaped, with their longer diameters parallel to the contours of the hills, but some have irregular polygonal shapes, due partly to faulting and partly to the angle between the erosion surface and the plane of the andesite-limestone contact (which the ores follow). The deposits at the contact have as a hanging wall either the fresh limestones or the silicated phase characteristic of the contact with the andesite. The ore protrudes irregularly into the limestone in large and small masses and veins. Small masses of the ore, measuring from a few inches to a few feet, lie entirely within the limestone, and fragments of limestone lie in the ore. Along fault planes the limestone is locally brecciated and cemented by ore for a few inches or a few feet, notwithstanding which the contacts on a large scale are usually even and continuous. The dip of the contact of the ore and the hanging wall is almost invariably steeper than the dip of the bedding of limestone—that is, almost vertical but with a slight dip away from the andesite.

The footwall is principally andesite, but at many localities the ore is separated from the andesite by a thin layer of the silicated contact phase or the sandy basal phase of the limestone. The contact with the footwall andesite as a whole is considerably more regular than that with the hanging-wall limestone. There is less interpenetration of the two masses, though some fragments of andesite do protrude into the ore or are entirely surrounded by it, and andesite breccias with ore cement are not uncommon along faults. Andesite dikes or offshoots are rare in the ores and limestone near the contacts but are known in one locality east of Iron Mountain. The andesite near the contact is altered to a soft clay retaining andesite texture. The contacts may be vertical or inclined but are commonly somewhat steeply inclined away from the andesite.

These simple relations of ore to wall rock are complicated by faulting to a considerable extent—probably to a larger extent than has been proved. Because of the faulting the ore may be nearly or quite surrounded by andesite or by limestone or by any combination of these rocks.

Much of the faulting is earlier than the ore deposition, as is shown by the fact that the fault breccias are cemented by ore, as in the Desert Mound and the Marshall claim in the Three Peaks area. Other faults are distinctly later than the ore, as on the Chesapeake and other claims on Iron Mountain.

The earlier and the later faulting are not certainly to be distinguished in all places in the present state of development of the deposits, for the structural relations are in part similar. The age of the late faulting of the ore deposits is provisionally assigned to the postlava period, because this has been a period of considerable faulting throughout the district.

The shape of the deposits in vertical cross section is incompletely known because exploration has been shallow. The general relation of the ore bodies to the inclosing rocks is shown in figure 63 (p. 574).

DEPOSITS IN BRECCIAS.

The ore constitutes cement or minute veins in fault breccias of Homestake limestone and Pinto quartzite at the Milner, Dear, Excelsior, Duluth No. 2, and Desert Mound claims, and of andesite at the Marshall, Blowout, Dexter, and Pot Metal claims. At the Desert Mound claim a fault breccia crosses andesite. Ore, limestone, and magnetite constitute breccia fragments.

ORES.

The ores as they appear above water level (beneath which pits have not yet been sunk) are mainly magnetite and hematite, usually intimately intermixed but locally segregated. The magnetite apparently constitutes about 70 per cent and the hematite 30 per cent of the whole. Deeper exploration may develop a higher percentage of hematite. At the surface the ore is ordinarily hard crystalline magnetite and hematite in porous, gnarled, and contorted masses, with coarsely crystallized quartz and fibrous chalcedony as the principal gangue mineral, wholly or partly filling cavities in the ore. Other gangue minerals occurring in small and practically negligible amounts are apatite, mica, siderite, diopside, garnet, pyrite, chlorite, calcite, barite, galena, amphibole, copper carbonates, limonite, and amethyst. Of these minerals barite and galena are more closely associated with the limestone than with the ore. Melanterite, associated with pyrite, was found in process of formation in the long tunnel on the Duncan claim. Beneath the surface the ore is usually softer and contains a larger proportion of soft bluish, reddish, brownish, grayish, and greenish banded hematite, limonite, and magnetite in greatly varying proportions and relations. The gangue materials are more abundant than near the surface, and calcite is in relatively increased proportion as compared with the quartz. The banding in the contact ores partly represents the bedding of the limestone, which the ore replaces. Banding in the dike or vein ores in the andesite is possibly the result of original deposition. Some of the softer ore at lower levels entirely lacks this banding. Locally, as on the west side of Lindsay Hill, the contact ore contains parallel streaks of a yellow clayey-looking mixture of iron carbonate, iron sulphate, glass, and probably some residual clay. Some of the narrow ore veins in the andesite possess a comb structure formed by the meeting and interlocking of apatite crystals which project from the walls, but in places do not entirely close the vein.

In the ore breccias the cements are magnetite, limonite, calcite, and quartz. At the Milner mine and elsewhere the magnetite has been deposited first about the fragments, here consisting of quartz, then hematite, then limonite, but exceptionally in the same locality the reverse order appears.

For the following information concerning the composition of the ores the writers are indebted to Mr. Fred Lerch, of Biwabik, Minn., and to Mr. R. N. Dickman, of Chicago, Ill., both of whom have exhaustively sampled the ores of the district for commercial purposes. Corroborative figures were obtained from other commercial sources, and a few analyses were made for the writers. In all, about 200 analyses from 400 samples of ores have been available, about two-thirds of them containing determinations only of iron, silica, and phosphorus, and one-third showing the percentages of all the common elements.

The average composition of the ores of the Iron Springs district, determined by combining all available analyses of the ores of the district from surface and pits, is as follows:

Average composition of iron ores of the Iron Springs district.

	Per cent.
Iron	56
Silica	7
Phosphorus	.200
Lime and magnesia	4
Alumina	1
Water	3

	Per cent.
Copper	.027
Sulphur	.057
Manganese	.196
Soda	1.19
Potassa	.80

The samples run as low as 45 per cent in iron and as high as 69 per cent. The hard ore in the andesite averages higher than the ore in the limestone. The ore at the surface, with few exceptions, has 3 to 12 per cent more iron than that below.

Phosphorus may diminish slightly in the deepest explorations (below about 100 feet), but its distribution is so irregular and capricious that this generalization is doubtful. Variations of 0.050 to 3.18 per cent occur within short distances, both vertical and horizontal. A few 10-foot samples of ore run below the Bessemer limit, but practically all the ore mined will be non-Bessemer ore.

Silica, averaging about 7 per cent, ranges from 2 to 28 per cent, the lower figures being more common in the ore in the andesite. Silica at the surface is about 4 per cent less than it is just below the surface.

Lime and magnesia range from 1.5 to 11 per cent. The hard ores in the andesite carry slightly less than the soft ores in the limestone. In both types the deeper ores carry the higher percentage. Both lime and magnesia increase relatively faster than silica with depth, the common ratio of silica to calcium and magnesium oxides at the surface being 2 to 1 by weight; and more nearly 1 to 1 below the surface.

Combined water ranges from less than 1 per cent in the magnetite to 4 per cent in the soft ores, averaging about 3 per cent. One determination of moisture in crystallized magnetite gives 0.45 per cent after heating to 110° C.

Sulphur averages 0.057 per cent. In the deep workings of the Duncan deposits it exceeds this figure and calls for serious consideration. No general evidence of increase with depth is apparent, but water level has not yet been reached.

Copper, titanium, and manganese are present but not in injurious amounts.

Soda and potassa are determined in a single specimen.

A comparison of average analyses of Iron Springs iron ores with Lake Superior hematites and with the Silurian hematites of Alabama is made in the following table. The Iron Springs ores are intermediate between the other two classes.

Average analyses of Iron Springs iron ores, Lake Superior ores, and Alabama ores.

	Iron Springs ores.	Lake Superior ores.[a]	Alabama hematites.[b]
Iron (metallic)	56	59.6	37
Silica	7	7.5	13.44
Phosphorus	.200	.067	.37
Lime and magnesia	4	1.3	16.2
Alumina	1	1.5	3.18
Water, above 220° F	3	4.0	.50
Copper	.027		
Sulphur	.057	.019	.07
Manganese	.196		
Carbonic acid			12.24

[a] Average cargo analyses for 1905.
[b] Birkinbine, John, The iron ores of Alabama (average analysis by W. B. Phillips): U. S. Geol. Survey Nineteenth Ann. Rept., pt. 6, p. 62, 1898.

TONNAGE.

The iron-ore deposits vary from mere stringers to those having an area of 1,670,000 square feet. The aggregate surface of all the ore deposits of the district is 5,430,000 square feet or 0.2 square mile.

The aggregate tonnage of all grades of ore in the district, determined by multiplying the known area by the best available information as to depth in pits, drill holes, and erosion sections, is 40,000,000 tons. The largest single deposit, figured on the same basis, has 15,600,000 tons. It is altogether likely that the figures are much too small rather than too large, because the depths used in the calculation have been those actually observed, and observation has not yet gone to the bottom.

GENESIS.

The principal ore deposits—those near the contact of the andesite and limestone—are partly replacements of limestone. The original bedding of the limestone has been preserved in the ore in places, and there is gradation between the ore and the limestone. These deposits also in part fill fissures in limestone or between limestone and andesite, or in andesite. The source of the iron-bearing solutions is the same for the limestone replacements and for the vein fillings in the limestone and in the andesite, for the mineralogic and textural characters are the same and in a few places they are actually connected. Sev-

eral hypotheses as to this source suggest themselves: (1) That the ore-bearing solutions were associated with the intrusion of the andesite as "igneous after-effects"; (2) that they were meteoric waters, cold, or heated by contact with the laccolith, acting after the laccolithic intrusions and before the eruption of the surface flows; (3) that they were hot solutions, magmatic or meteoric or both, connected with the late eruptives of the district, deriving the ores from the extrusive or from the underlying rocks; (4) that they were cold meteoric waters later than the extrusive rocks; (5) that they were due to some combination of these sources. The deposition of the ore is best explained by the first hypothesis, but later concentrations of the ore have occurred in the order given.

For a detailed discussion of the several hypotheses the reader is referred to Bulletin 338. The processes that are believed by Leith and Harder to have produced the deposits as they are now are briefly summarized by them essentially as follows:

Andesite laccoliths were intruded in Paleozoic and Mesozoic sediments, with consequent tilting of the strata in quaquaversal manner about the laccolith and contact metamorphism of the zone adjacent to it, accompanied and followed by fissuring, jointing, and faulting. Hot ore-bearing solutions entered through fissures in the andesite into the adjacent sediments, depositing ore as dikelike masses in fissures in the andesite, as fissure fillings and replacements in the limestone, and as cements in breccias of andesite, limestone, and quartzite. The solutions introduced also garnet, diopside, amphibole, phlogopite, apatite, calcite, quartz, and pyrite, most of which had also been developed in the limestone by the preceding contact metamorphism. Soda was conspicuously increased in the wall rocks. It is thought that the solutions were pneumatolytic aftereffects of the andesite intrusion.

Erosion developed mountains with andesite cores, encircled by belts of sediments at uniform elevations on the slopes, except where displaced by faults or where cut back by differential erosion. The areas between the mountains were left with low relief. The ores were exposed and partly eroded calcite, apatite, and perhaps other gangue materials were leached and redeposited below. There was more or less oxidation and hydration of the ores along fissures beneath the surface.

Tertiary lavas were extended over the entire area, furnishing hot magmatic waters and heat to meteoric waters and thereby developing coarsely crystalline magnetite and hematite in the ore deposits and especially at the surface, leaching the gangue materials so far as they were left by weathering near the surface, and depositing in the cavities chalcedony and to a slight extent magnetite, hematite, limonite, siderite, chlorite, barite, calcite, galena, and the copper carbonates.

Erosion reexhumed the andesite mountains from under the lavas and brought to light the sediments and ores on the slopes, a process accompanied by local surface oxidation and hydration of the ores and leaching of the gangue materials, chiefly calcite but also apatite. Differential erosion caused some of the ore outcrops to stand above the adjacent rocks, but others, whose hard cap had been eroded away, were cut well down to the level of adjacent rocks. Faulting of the ore deposits preceded and accompanied the erosion, developing structural relations all of which can not be distinguished from those determined by faulting before deposition of the ores.

Should the lavas prove to be older than the intrusive rocks, several of the above steps would be eliminated.

BULL VALLEY DISTRICT.[1]

GENERAL FEATURES.

The Bull Valley district lies about 25 miles southwest of the Iron Springs district, extending from Garden Springs on the northeast southwestward to Bull Mountain and 40 to 50 miles beyond. (See fig. 64.) The district, which has only recently been explored and staked, is much more difficult of access than the Iron Springs district and is consequently less well known. The nearest railway station is Modena, 28 miles distant by way of Enterprise.

The principal ore deposits lie several miles below the headwaters of Moody Run, which empties into Magotsu Creek 10 miles below the Mountain Meadows. From this point they extend eastward about 3 miles to Garden

[1] Abstracted from Leith, C. K., and Harder, E. C., The iron ores of the Iron Springs district: U. S. Geol. Survey Bull. 338, pp. 90-92, 1908.

Springs, a short distance west of the Mountain Meadows monument, the site of the famous Mountain Meadows massacre. To the southwest, deposits occur on Bull Mountain 2 or 3 miles distant and on Cove Mountain an equal distance beyond.

GEOLOGY.

The essential geologic features of the district are the same as those in the Iron Springs district—a series of laccoliths, surrounded by sediments dipping quaquaversally away, again surrounded and overlain by flat-lying lavas, the whole being bounded on north and west by later flows of basalt. The topography is

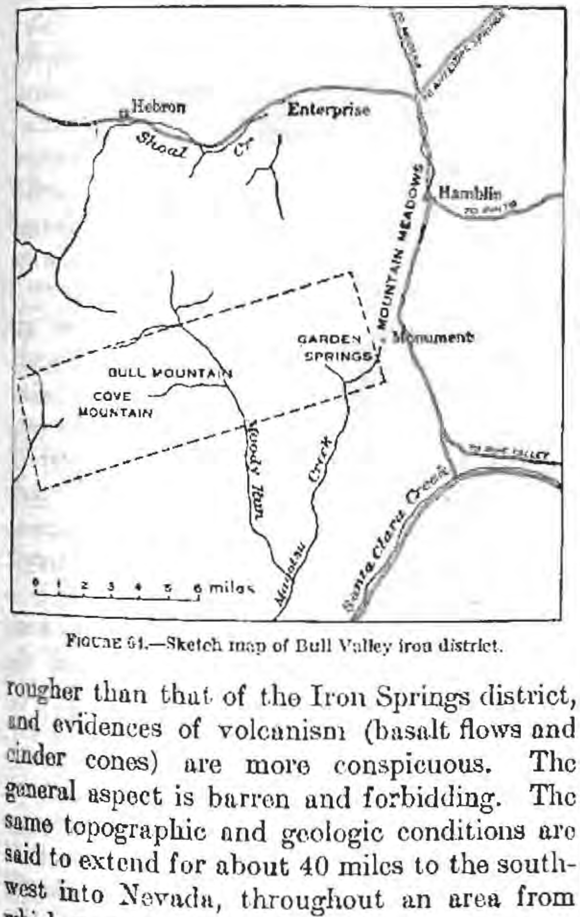

FIGURE 51.—Sketch map of Bull Valley iron district.

rougher than that of the Iron Springs district, and evidences of volcanism (basalt flows and cinder cones) are more conspicuous. The general aspect is barren and forbidding. The same topographic and geologic conditions are said to extend for about 40 miles to the southwest into Nevada, throughout an area from which ores are reported.

ORE DEPOSITS.

The ore deposits were examined in their discontinuous occurrence between the headwaters of Moody Run on the west and Garden Springs on the east and were found to be similar in almost every feature to those of the Iron Springs district. The principal deposits are associated with limestone fault blocks that lie within the andesite, and subordinate deposits follow the main contact of andesite and limestone, which strikes southwest across Moody Run and dips southeast. Flat-lying flows fringe the ore-bearing areas. On the south are acidic flows and tuffs, on the north acidic flows and tuffs and basalts. A white band near the base of the acidic lavas is very conspicuous and in most of the district is sufficiently near the limestone-andesite contacts to make it a useful marker for the ores.

The greatest width of ore observed at the surface was 115 feet but was not sufficiently well exposed to make it certain that this 115 feet was continuous ore. This particular deposit has a length of approximately 700 feet.

The iron is both magnetite and hematite, as in the Iron Springs district, but the hematite on the lower slopes has a fine granular texture and a steel-blue color which is not seen in the Iron Springs district.

The composition of the ore at the surface, as sampled by Lerch Bros., is as follows:

Composition of the Bull Valley district ores.

[Analyst, Fred Lerch, Biwabik, Minn.]

	Iron.	Phosphorus.
Across 150 feet, Pilot No. 9	58.98	0.195
Across 250 feet, Pilot No. 8	62.38	.217
Across 60 feet, Pilot No. 7	62.06	.163
Pilot No. 12	66.40	.072
Across 40 feet, Pilot No. 7	64.13	.434

A little pitting, trenching, and tunneling has scratched the upper parts of the deposits.

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SILVER REEF (HARRISBURG, LEEDS) DISTRICT.

By B. S. BUTLER.

GENERAL FEATURES.

The Silver Reef district is in the east-central part of Washington County in southwestern Utah. Leeds is in its central part, Toquerville is about 6 miles to the northeast, and St. George about 20 miles to the southwest. The district can be reached from Modena on the Los Angeles & Salt Lake Railroad by way of St. George, a distance of about 90 miles, or from Lund by way of Cedar City, a distance of about 70 miles.

The region is arid. In the lowlands, in the vicinity of the mines, there is no timber and for the most part only a scanty growth of desert plants. In the Pine Valley Mountains there are cedar and other trees suitable for wood and timber. Water is scarce. A stream from the Pine Valley Mountains supplies water for the settlements at Leeds and Harrisburg, for the irrigation of small areas, and for milling at Silver Reef. Virgin River is only a few miles from Silver Reef and touches the northwest end of East Reef. Some milling was done on the river.

Virgin River is a good-sized stream and furnishes ample water for all purposes. The soil is apparently fertile and where properly irrigated yields abundant crops. Both the soil and climate appear especially well adapted to the cultivation of grapes, peaches, and similar fruits. Farming is confined to small areas that can be irrigated, but the agricultural possibilities seem sufficient to supply any probable local demands; and most agricultural products can be obtained at reasonable rates. The absence of a railroad is a serious drawback to farming, and a local demand would greatly stimulate that industry.

The climate is mild and delightful in winter but is hot in summer. Rainfall is light, the average yearly precipitation at St. George for 19 years ranging from 3.55 to 18.71 inches (average 8.66 inches).

TOPOGRAPHY.

In the immediate vicinity of Silver Reef the region is rough, but the relief is not great. The elevation here is about 4,000 feet. Northwest of Silver Reef the strong cliff-making members of the Triassic and Jurassic formations and the volcanic rocks of Pine Valley Mountains produce a very rugged topography, the mountains rising to 10,000 feet, or about 6,000 feet above Silver Reef. A few miles east the great Hurricane Cliff forms the western front of the Plateau Province, and still farther east a succession of benches and cliffs extend up the valley of the Virgin as far as the eye can reach.

Northeast and southwest from Leeds extends a broad anticline of soft shales overlain by hard conglomerate. A few miles below Leeds weathering has cut through the conglomerate and has carved a deep valley in shales beneath from which the harder beds stand out as ridges. Vegetation is almost lacking; and its name, "Little Purgatory," seems especially appropriate. Leeds is in a strike valley eroded in the soft shales between the hard Shinarump conglomerate and the sandstones forming the silver reefs.

GEOLOGY.

SEDIMENTARY ROCKS.

The sedimentary rocks of the Silver Reef district range in age from upper Carboniferous to Tertiary. The region has been studied in some detail by Huntington and Goldthwait,[1] and the following general descriptions and geologic map (Pl. XLVI, in pocket) and section (fig. 65) are taken from their paper.

The Aubrey formation, in the Toquerville district, consists of a rather massive gray limestone, capped by a series

[1] Huntington, Ellsworth, and Goldthwait, J. W., The Hurricane fault in the Toquerville district, Utah: Harvard Coll. Mus. Comp. Zool. Bull., vol. 42, pp. 201-259, 1904.

of colored shales. The limestone resists erosion with much strength. Where it has been cut by the recent Hurricane fault, it stands up as a steep ragged wall. * * * East of the fault scarp the Aubrey stretches away as a broad platform, which for miles has been swept clean of the overlying Moencopie shales. It extends from Toquerville clear to the Grand Canyon, a vast yellow dust-covered plain, thinly drained by dry washes, with here and there a low limestone ridge, a black basaltic cone, or a highly colored Moencopie mesa.

The Moencopie shales, when protected by the strong Shinarump cap, stand up in broad ragged mesas that are remarkable for both color and sculpture. From the top of one of these tables to the plain at its base, the bare slopes descend very steeply, with an occasional narrow bench, limited by a cliff, where a harder member asserts its strength. Seen from a distance, the alternating horizontal bands of chocolate, gray, lavender, and red stand out with ribbon-like uniformity and distinctness. In contour these tables are very irregular, with long headlands and reentrants, down the slopes of which are cut innumerable gullies and ravines, systematically placed, so as to form a minute pattern of tapering, branching, and sprawling spurs that give the impression of a conventional design. Where the shales have lost their conglomerate cap, however, they have either been dissected into a choppy badland topography of gullies and ridges, or, as is more often the case, they have melted away into broad, gently sloping grade plains, which stretch out from the escarpment for miles, until at last they merge into the Aubrey platform.

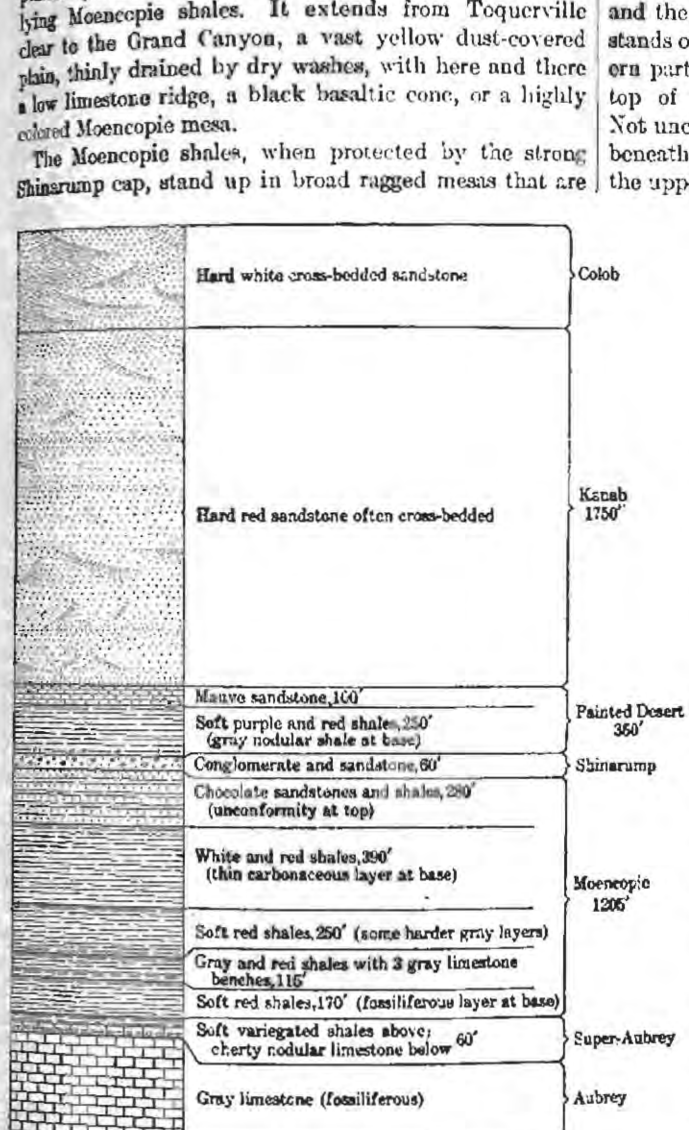

FIGURE 65.—Section of rocks exposed along Le Verkin Canyon between Toquerville and Colob. After Huntington and Goldthwait.

In sharp contrast to the weak Moencopie shales below and the soft Painted Desert shales above, the Shinarump stands out firmly as a bench and cliff maker. In the eastern part of our area, among the plateaus, it forms the flat top of the "Permian" terrace, and its outlying tables. Not uncommonly its edge projects out over the soft shales beneath, like an ornamental molding. Often, where it is the uppermost member remaining, its top is flat and clean, but where it merely flanks the bold Kanab escarpment its platform is banked by landslides from above. This is well shown at Rockville, near the Virgin River, where the waste of the shales is particularly rapid.

Where the strata have been folded the Shinarump again is conspicuous. Between Toquerville and St. George, where a great plunging anticline has been unroofed by erosion, the conglomerate forms a cigar-shaped hill, splitting at its southern end so as to surround a long amphitheater. * * *

The Painted Desert formation is a series of shales, elsewhere chiefly clay shales, but in the Toquerville district more sandy. Although varied in color, they are uniformly weak.

At the top of the Painted Desert series, as we have limited it, and at the base of the Kanab, there is a thick sandstone member, of a lavender or mauve color, and of such hardness that it often forms a bench above the shales, after the manner of the Shinarump, though hardly so conspicuously. * * *

Above the mauve sandstone, at the base of the Kanab, is a thin series of weak beds whose nonresistance permits the development of the platform beneath; then comes about 1,700 feet of uniformly hard, brick-red sandstone, occasionally cross-bedded. It is the unusual thickness and massiveness of this hard sandstone formation that makes it the greatest cliff builder in the region. * * * Although at Rockville its imposing front trends toward Toquerville, it turns rather sharply, a few miles east of Lo Verkin Creek, and runs northwest to Colob. The architecture of the Kanab is massive and grand. Lofty though the red cliffs really are, their height is even exaggerated, as a result of prominent vertical jointing, by deep rifts which cut the cliffs from top to bottom. Below, the rifts show as sharp upright slits through the rock, but at the top they widen out into ragged gashes, chopping up the rock into pinnacles and spires.

Within the limits of our map the Kanab does not attain this grandeur of form. Only along the eastern base of the Pine Valley Mountains is the entire formation exposed, and there it has an ancient subdued topography. * * *

The Colob formation also, in the vicinity of Toquerville, is not displayed to best advantage. Along the Pine Valley Range it forms rounded foothills and long sloping

ridges, which have little individuality aside from their pure white or occasional buff color. Far to the eastward, at the Temples of the Virgin, and along the marvelous White cliffs, the more magnificent features of sculpture are brought out by active erosion. Even in our region, however, where recent erosion has been actively at work, the structural detail of the Colob is well shown in long sweeping curves of cross-bedding. The slow crumbling away of the fine white sand grains brings out the frostwork pattern in a way that is at once pleasing and grotesque. The mysterious name "Colob" is well suited to it.

The Cretaceous and Tertiary formations are not well exposed in the immediate vicinity of Silver Reef and were not examined. In the Iron Springs district to the northwest, Leith and Harder (see p. 569) have described a section consisting of 1,500 feet of Cretaceous sandstone, shale, conglomerate, and limestone resting unconformably on Carboniferous limestone and overlain unconformably by 1,000 feet of Eocene limestone, conglomerate, and sandstone.

The correlation of the section of Huntington and Goldthwait with the Colob section of Dutton is shown in the following table:

Correlation of rocks of Silver Reef district with Colob Plateau.

Silver Reef (Huntington and Goldthwait).	Colob Plateau (Dutton).
Tertiary limestone, shale, and conglomerate.	Tertiary limestone, shale, and conglomerate.
Cretaceous sandstone, shale, and limestone.	Cretaceous sandstone, shale, and limestone.
Colob sandstone.	Jurassic shale. Jurassic sandstone.
Kanab sandstone. Painted Desert sandstone and shale. Shinarump conglomerate.	Triassic sandstone, shale, and conglomerate.
Moencopie shale and sandstone.	Permian shale and sandstone.
Super-Aubrey shale and limestone. Aubrey limestone.	Carboniferous limestone.

IGNEOUS ROCKS.

Igneous rocks were not observed in place in the immediate vicinity of Silver Reef. The abundance and large size of the igneous fragments that litter the surface to the north and west suggest that they originated close at hand. Closer examination, however, indicates that they were derived from the igneous rocks in the Pine Valley Mountains or from a southward extension of that body that has since been removed by erosion and were transported to their present position by some means whose nature is not clear.

The igneous rocks in place in the region consist of the extensive lava flows in the Pine Valley Mountains, of a small body of similar rock about 2 miles south of Bellevue, and of extensive flows of basaltic rocks that extend for many miles along the front of the plateau.

The rocks of the Pine Valley Mountains are evidently similar to the extrusive rock of the Iron Springs district. No intrusive bodies have been reported in the Pine Valley Mountains, but they have never been carefully sought for and may be present. The flows in the Iron Springs district [1] range from andesites to rhyolites, and the rocks farther south are probably of the same general character.

The character of the body south of Bellevue has not been definitely determined. Huntington and Goldthwait state that "the smaller andesite hills near Toquerville are either intrusive portions which never reached the surface or stocks of extrusions of which all other traces have been removed." All the flow rocks in the general region are believed to be of Tertiary age, and rest upon Eocene sediments, as has been shown in the Iron Springs district. Rocks of the same general character between Bellevue and Toquerville are in contact with Jurassic and Cretaceous sediments, and if they are of the same age as those to the northwest their position is most naturally interpreted as being due to intrusion. Neither in the very short time available for field study nor in later study of specimens was the writer able to find positive evidence of their relations to the sedimentary rocks, for they are porphyritic and have a fine crystalline groundmass whose texture is duplicated by both intrusive and extrusive rocks. From their position in the sedimentary series they are regarded tentatively as of intrusive origin.

To the west of the Hurricane scarp for several miles north and south of Toquerville are large bodies of basaltic lava, and similar rocks are found to a lesser extent east of the scarp.

The earlier rhyolitic, latitic, and andesitic lavas rest upon Eocene sediments and are probably of Miocene age. The basaltic flows are much later and may all be classed as Recent, though their accumulation has been in progress over a long period. Some of the earlier flows have been extensively eroded, but others show so little change that they may be only a few hundred years old.

[1] Leith, C. K., and Harder, E. C., The iron ores of the Iron Springs district, southern Utah: U. S. Geol. Survey Bull. 338, p. 17, 1908.

STRUCTURE.

Folding was the principal factor in producing the structure in the immediate vicinity of Silver Reef, though both folding and faulting have been important in the general region.

Following the deposition of the Eocene sediments and probably the extrusion of the earlier lavas, the region was thrown into a series of broad open folds having a general northeast trend. This series of folds has been described by Huntington and Goldthwait as follows:

East of a line drawn along the southern portion of the Hurricane fault and extended northward up the valley of La Verkin Creek the strata are nearly horizontal. Between that line and the old shore line of the Mesozoic Sea west of the Pine Valley Mountains the strata are compressed into two synclines and two anticlines which culminate in a great overturned fold at Kanarra. North of Kanarra the continuation of these plications was not studied; toward the south they gradually die out until, 15 or 20 miles beyond Toquerville, they have greatly broadened and persist only as gentle monoclines dipping toward the east. The most western of these folds is the broad gentle syncline in which lies the lava of the Pine Valley Mountains. In the neighborhood of the mountains the dip is everywhere gentle, and the flat bottom of the trough is several miles wide. Toward the southwest this syncline almost vanishes, but the western limb seems to persist as an eastward-dipping monocline whose lower limit is now the Grand Wash fault.

The next fold to the east is a remarkable anticline which runs northeast 18 miles from Price City south of St. George to Leeds, where it bends more to the north for 10 miles, until it is lost under alluvium and lava a short distance north of Bellevue. When what seems to be the same fold reappears at Kanarra it has again bent somewhat to the northeast. Although near St. George this fold is finely exposed as a typical breached anticline, that portion fades into insignificance when compared with the extraordinarily diagrammatic portion near Harrisburg and Leeds. Here erosion had removed all the strata as far as the Shinarump, which at Leeds forms a great rounded nose pitching toward the north and shaped like the decked front of a round-topped canoe. As the anticline rises toward the south the deck of the nose gains a greater elevation, until, halfway from Leeds to Harrisburg, the center is broken open where it has been undermined by the wearing away of the soft Moencopie shales. A few miles farther south, a five minutes' walk from the road southwest of Harrisburg, brings one to the top of the Shinarump Cliffs on the northwest side of the anticline. Under the observer's feet is the hard Shinarump formation dipping 40° NW. On its resistant surface erosion proceeds very slowly, and for many miles this edge of the anticline forms a ridge. In front of the observer a precipitous cliff 50 or 60 feet high bounds abruptly a perfect anticlinal trough, a mile or more wide, a sort of hand specimen or model showing at a glance a diagrammatic type not only of an anticlinal trough but also of an anticlinal ridge. Under the Shinarump Cliffs lie the bright-colored Moencopie shales, red, gray, and brown, the edges of which are truncated like those of the overlying sandstone and conglomerate, although at a lesser angle. At the very center lies a little rounded ridge where erosion has laid bare the harder underlying Aubrey limestone, which rises as an anticlinal core in the midst of an anticlinal trough. Beyond the ridge the naked particolored shales again rise gradually in brilliant bands to a Shinarump Cliff exactly like that on which we are standing, except that it faces in the opposite direction and dips to the southeast.

North of Bellevue where the fold disappears under a covering of lava it is still a normal anticline, but where what seems to be the same fold reappears at Kanarra it has been compressed to such an extent that it has been completely overturned and the strata lie in inverted order with a rather steep dip to the northwest. As this fold has been cut at this point by both the old and the new Hurricane faults, only a small portion is now exposed.

The trough lying east of this anticline is unimportant. It dies out completely south of Toquerville, while at Kanarra it is so far compressed that the two limbs touch each other. The most eastern anticline lies close to the line of the Hurricane fault. On the south it flattens out, although the eastern limb persists as an eastward-dipping monocline, at the base of which is the Hurricane fault. In the northern half of the region it is a strong arch with a dip of from 20° to 40°. The ridge east of Bellevue is formed where it brings up a hard core of Aubrey limestone which has since been bisected longitudinally by the Hurricane fault. On the eastern side of this core all the overlying strata have been stripped off; on the western side where the country has been dropped far down by the fault, the overlying strata are to a great extent preserved.

Faulting in the immediate vicinity of Silver Reef has not been important. A few miles to the east, however, is the great Hurricane fault marked by the Hurricane cliff, where faulting on a grand scale has taken place. This fault can be traced with a general strike east of north for scores of miles north and south from this region, and its displacement is measured by hundreds of feet. Movement along this line began much later than the folding of the region (possibly in late Tertiary time) and has continued intermittently till very recently if not to the present time.

HISTORY AND PRODUCTION.

By V. C. Heikes.

Huntley,[1] who visited the district in July, 1880, says:

Harrisburg district, better known as Silver Reef, is in the eastern part of the county, and covers an area of about 5 miles square. The old Mormon town of Leeds was the settlement nearest the mines in early times, and also gave a name to the region. As the mines were developed, the town of Silver Reef was built. * * * Silver was dis-

[1] Precious metals: Tenth Census U. S., vol. 13, pp. 477-482, 1885.

covered in 1869 by John Kemple, who found, near Harrisburg, a piece of float which assayed $17,000. He filled up his small shaft and left the country, but returned with others and organized the district June 22, 1874. He worked his claims for a few months, when becoming discouraged, he returned to Star district. * * * The district owes its development entirely to Mr. W. T. Barbee, who went there in the summer of 1875. He discovered very rich ore on the Tecumseh claim, and shipped 10 tons of $500 ore to Salt Lake City in the following November. He continued the shipments of ore to Salt Lake City and to Pioche during the following year. This caused the rush to the district, principally from Pioche, in the summer and fall of 1876. The recorder's books showed 640 locations, but probably not over 150 claims were owned at the period under review. * * *

Mills have been erected in the district in the following order: Leeds, February, 1877; Pioneer, three-stamp, demolished fall of 1877; Christy, January 8, 1878; Barbee & Walker, March, 1878; Stormont, July 4, 1878. In 1877 and 1878 many rude leaching works were erected. * * *

The total production of the district has been * * * $3,243,738.92.

Beginning at the northern extremity of each reef the important mines are located in the following order:

White reef.—Barbee & Walker, Pinkham & Dodge, Leeds, Thompson & McNally, and Gisborn.

Buckeye reef.—Silver Flat, Manhattan, Tecumseh, all three belonging to the Christy Co.; Kinner, Buckeye, Last Chance, owned by the Stormont Co.; Maggie, California, both belonging to the Christy Co.; and Emily Jane.

East reef.—Vanderbilt, Duffin, Dykes & Stapeley, Toquerville, Maud, and Dixie.

The other mines of the Silver Reef or Harrisburg district are:

Mines of the Silver Reef district.

Mines.	Total length of openings.	Total product.	Remarks.
	Feet.		
Pinkham & Dodge	727	No ore shipped.	Large bodies of $16 ore.
Emily Jane		280 tons.	Ore, $20 and $30; developments limited.
Vanderbilt		240 tons.	Average of ore produced $100; incline of 60 feet.
Duffin	900		Total product, many hundred or thousand tons of $80 to $100 ore.
Toquerville	1,000		Several hundred tons of $50 ore shipped.
Maud	440	$33,986.	Ore assays from $30 to $100.
Dixie	100	400 tons.	Ore produced valued at $35 per ton.
Gisborn		500 tons.	Value of ore produced $20 to $25 per ton.

Several of the leaching works erected in the district were operated on tailings till the Stormont closed in 1887, when they too were suspended. In March, 1889, the Christy Co. stopped work, practically closing the camp. From 1890 to 1909 occasional lots of silver were recovered from ores worked under a lease in the Brundage mill from the Leeds, Thompson, Red Star, Free Coinage, and Wonder claims.

The Silver Reef district yielded silver annually from 1875 to 1897, when production ceased. It began again in 1902 and, except for 1906, continued until 1909. The production of the district between 1875 and 1902 has been compiled from the records of the Director of the Mint and from 1903 to 1909 from the records of the United States Geological Survey. The output arranged by periods is as follows:

Production of Silver Reef district, 1875–1909, by periods.

Period.	Silver recovered.	Total value.[a]
	Ounces.	
1875–1880	3,319,054	$3,808,890
1881–1890	3,590,598	3,966,118
1891–1900	206,069	158,140
1901–1909	95,742	53,994
	7,211,463	7,987,142

[a] Average commercial price used for silver to make total for each calendar year.

Some of the operating companies in the Silver Reef district were close corporations, and it is difficult to ascertain what was paid in dividends. The amount has been variously estimated from $900,000 to $1,300,000.

ORE DEPOSITS.

OCCURRENCE AND CHARACTER.

The workable ore deposits occur in the "Painted Desert formation" between the Shinarump conglomerate and the massive red Kanab sandstone of Huntington and Goldthwait. In the vicinity of Silver Reef the lower 200 to 300 feet of the "Painted Desert formation" consists of weak shale and sandstone, which have been deeply eroded and underlie Leeds Valley. Overlying this shale series is a massive sandstone varying from reddish to gray, which outcrops as a rather prominent ridge (Butte Reef). Between this sandstone

A. VIEW LOOKING NORTH ALONG WHITE AND BUCKEYE REEFS IN THE SILVER REEF DISTRICT.

White Reef at left; Buckeye Reef at right.

B. VIEW LOOKING SOUTH ALONG BACK SLOPE OF WHITE REEF, SILVER REEF DISTRICT.

A. SPECIMEN OF CLAY CONGLOMERATE ORE, SILVER REEF DISTRICT.
View parallel to bedding.

B. SPECIMEN SHOWN IN *A* VIEWED ACROSS BEDDING, SHOWING LENTICULAR FORM OF CLAY "PEBBLES."

C. SPECIMEN OF SILVER ORE FROM WHITE REEF, SILVER REEF DISTRICT, SHOWING FOSSIL PLANT REMAINS.

and the Buckeye Reef is about 100 feet of shaly beds. Overlying the Buckeye Reef is about 50 feet of shale, overlain by the relatively massive gray sandstone of the White Reef, which outcrops prominently for several miles. Between White Reef and the Kanab sandstone of Huntington and Goldthwait are several hundred feet of weak shales whose position is marked by the lowland between the reef and the sandstone cliff. (See Pl. XLVII.)

The dip of the beds necessarily varies from point to point. West of Leeds, where the reefs are nearly parallel, the dip is 20°–40° W., but to the north, where the beds swing around the nose of the anticline, the dip changes from west to north and becomes much less. It is also stated that the dip varies somewhat with depth. On the East Reef the conditions are essentially similar to those to the west, except that the direction of the dip is reversed.

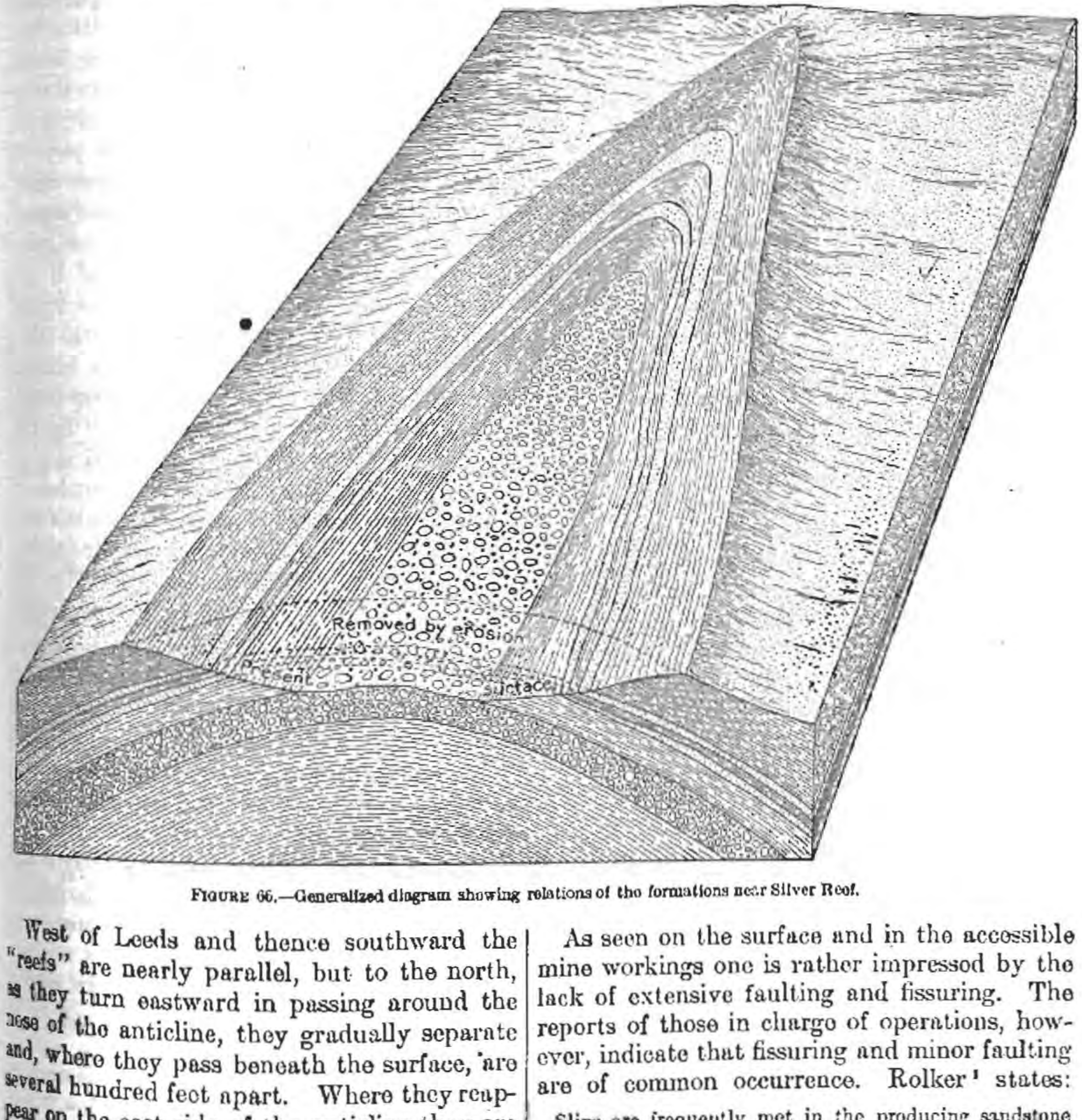

FIGURE 66.—Generalized diagram showing relations of the formations near Silver Reef.

West of Leeds and thence southward the "reefs" are nearly parallel, but to the north, as they turn eastward in passing around the nose of the anticline, they gradually separate and, where they pass beneath the surface, are several hundred feet apart. Where they reappear on the east side of the anticline they are less distinct and are generally spoken of in combination as the East Reef, though they have been worked and can doubtless be traced as separate strata or reefs. The relations of the formations are generalized in figure 66.

As seen on the surface and in the accessible mine workings one is rather impressed by the lack of extensive faulting and fissuring. The reports of those in charge of operations, however, indicate that fissuring and minor faulting are of common occurrence. Rolker[1] states:

Slips are frequently met in the producing sandstone beds. Some of these slips are caused by very fine fissures or cracks, as fine as a sharp blade of a knife. They sometimes throw the ore into the over or underlying [beds] producing side branch. In some cases they also cause the

[1] Rolker, C. M., The silver sandstone district of Utah: Am. Inst. Min. Eng. Trans., vol. 9, p. 29, 1881.

silver to pinch out entirely. Often they are also the leaders to a new deposit. Faults are met with, which throw the silver-bearing stratum from a few inches to several feet within the same line of bedding. The faulting lines are usually filled out with clay, and they generally contain silver. The faults and slips occur in all the mines. I append a sketch of two types, figure 67 being

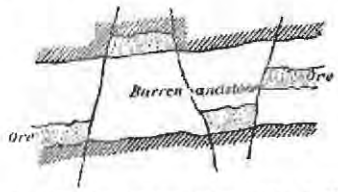

FIGURE 67.—Faulting, Buckeye mine. After C. M. Rolker.

from the Buckeye mine and figure 68 from the Last Chance mine.

The silver solution seems to have left its traces in some of these faulting lines, being prevented, of course, from impregnating the immediate sides by the clay lining, until it found an easily permeable stratum above or below. The faulting lines were formed during and after the tilting took place and previous to the silver deposition.

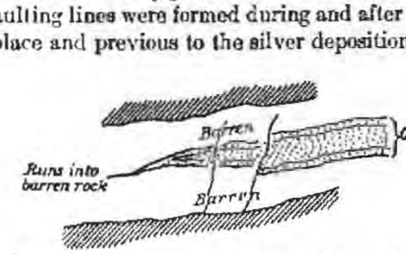

FIGURE 68.—Faulting, Last Chance mine. After C. M. Rolker.

The central portion of the Buckeye Reef, on its west branch, shows for about 400 feet in length a reverse dip (to the east), forming a complete curve, following the bed down on its dip, and showing the upper portion of this curve faulted 40 feet off to the west. In the Kinner mine, in one place it shows, besides, a doubling up before

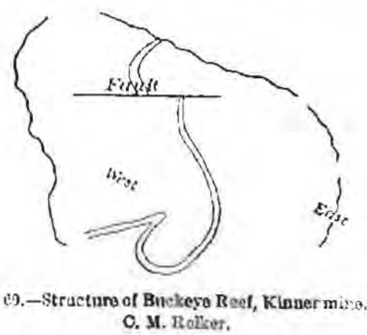

FIGURE 69.—Structure of Buckeye Reef, Kinner mine. After C. M. Rolker.

it assumes the regular west dip, as is indicated in the accompanying sketch.

The ore occurs in irregular shoots at different positions within the "reefs," and it pinches and swells along the dip and strike. (See fig. 70.) Much of the rich ore is associated with carbonized vegetable remains, either stems 6 to 8 inches in diameter and several feet long or small rushlike bodies. (See Pl. XLVIII, *C*.) The plants have ordinarily been partly silicified and partly carbonized. Some of the larger fragments have been largely replaced by silica, and in these the silver content is said to be small. On the other hand, the highly carbonized plants are favorable localities for the precipitation of minerals.

Not all the ore, however, is closely associated with plant remains. Considerable silver has been obtained from a peculiar conglomerate consisting of a sandy matrix containing flat lenticular lenses of clay shale whose length ranges from a small fraction of an inch to 3 inches and whose thickness is uniformly much less. The lenses are flattened in the plane of the stratification. The lenses show pronounced slickensiding where broken, and have apparently resulted from the flattening of more spherical bodies. The silver mineral is apparently present both in the sandstone matrix and on the slickensided faces in the clay lenses. (See Pl. XLVIII, *A*.)

Silver is also obtained from "soapstone," a rather thin stratum of shale or clay that has been slightly sheared in folding and is composed of small lenticular bodies bounded by slickenside faces. In some localities this clay material can be broken to minute fragments, each bounded by slickenside faces. The ore minerals apparently lie along the slickenside planes.

Much of the ore is said to have been sandstone, not differing greatly from the normal sandstone of the "reefs." The mineralized sand rock is usually composed of rather thin lamellae, is iron stained, and contains nodular masses of clay and iron that are said to contain a relatively large amount of silver and other nodules that are composed largely of iron oxide cementing quartz and strongly suggesting altered pyrite. Massive beds of sandstone inclosed in these "shoots" are said to be commonly too low in silver content to be of commercial value.

Rolker[1] gives the following description of the reefs:

The reefs themselves are made up of whitish-gray and red to reddish-brown sandstones, and between the reefs lie beds of clay shale, varying in color from blue to green to cinnamon brown. The ore occurs in similar strata of

[1] Op. cit., pp. 24-26.

sandstone and clay shale. The roof is generally marked by a reddish micaceous sandstone, while the floor is made up of an arenaceous sandstone of a whitish color, with argillaceous sands underlying. The outcrop of the ore is marked on the east face of the reef, with the exception of those places where the former apex of the reef has been washed off, as in portions of the Buckeye Reef on its northwest side of the horseshoe. The ore is by no means confined always to one bed, but it is limited to a silver zone of from 30 to 90 feet wide, horizontally measured, and anywhere within this belt the horn silver is liable to be found. As a rule it is more concentrated in certain layers (beds) of this belt, but in places it is so scattered as to bring the grade down to a uniform $10, which at present does not pay to work. Frequently, also, the ore is thrown in consequence of very fine slips from one bed into another. Hence the giving out of the ore in one bed is not exactly a discouraging fact, for a cross-cut may, and very often does, prove it to have jumped into a lower or higher bed, respectively. In other words, the argentiferous sandstone belt is compound in structure. The producing branches, two or three in number, run together in places, at least two of them do, and then again continue for long distances with barren strata between, which vary in thickness from 3 to 15 and even 20 feet or more. In the depth, or following the dip, they have kept pretty well their own ground, but I have no doubt that what is now considered two and three separate beds will at a greater depth form but one bed throughout. The producing branches in all the mines change occasionally from a sandstone to a clay shale, even in the same bed, but certain portions of the reef, especially the northwestern portion of the Buckeye Reef, and the southern and a part of the central portion of the White Reef, show a preponderance of clay shale and argillaceous sandstone. The latter strata are also found in some of the northern parts of the White Reef.

Of course the less clayish or argillaceous the sandstones the less slimes are produced in the mill. The southern and part of the middle portion of the Buckeye Reef show less frequently vegetable remains than the remaining portion and the White Reef, and in parts these remains are absent. In other parts, and this holds true for the whole district, we find the producing sandstone beds underlaid by a stratum of highly argillaceous sandstones of variable thickness of from 10 inches to 2 feet, which carry much silver, and frequently show solid sheets of horn silver along the seams of the thickness of a knife blade. I have known such seams to mill right along from $60 to $130; unfortunately their occurrence is not as frequent as might be wished.

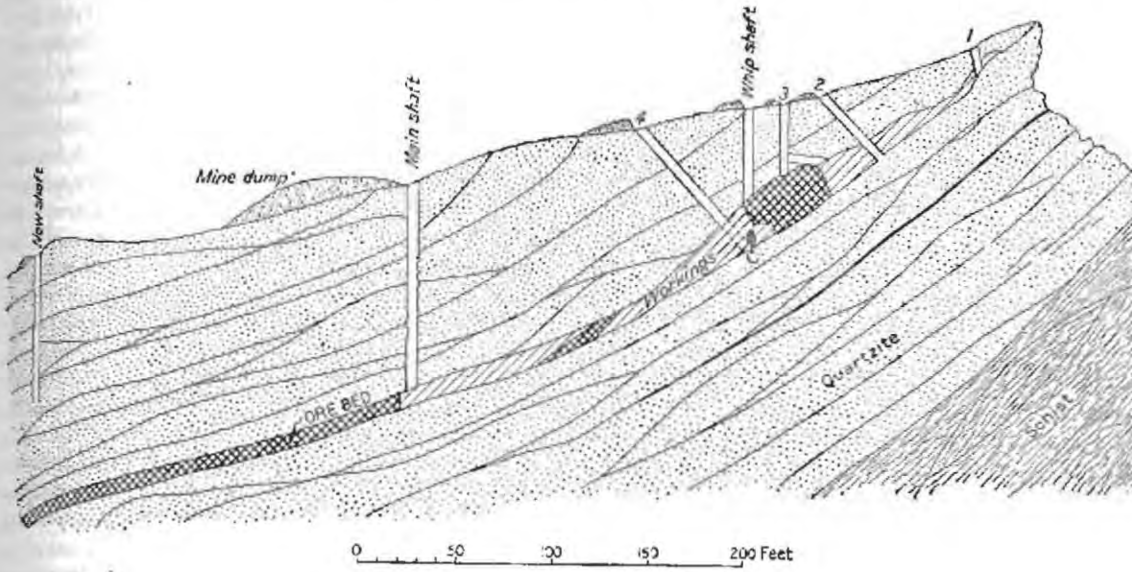

FIGURE 70.—Vertical cross section of Last Chance mine.

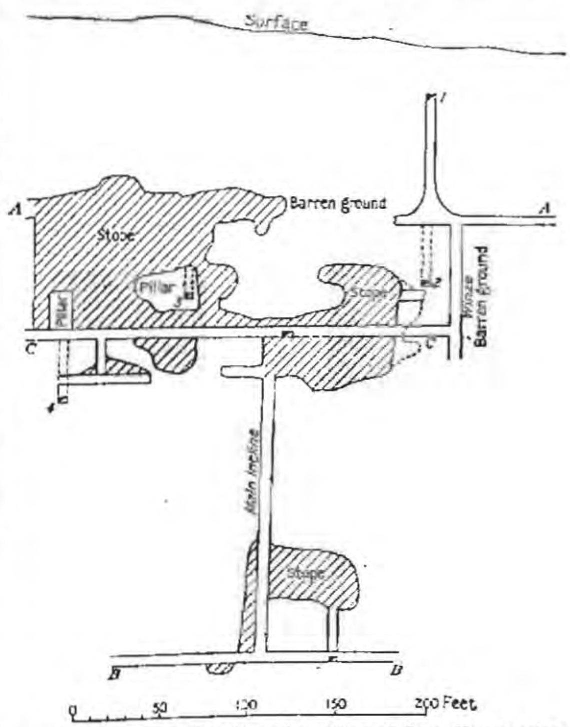

FIGURE 71.—Longitudinal section of workings of Last Chance mine, projected at plane of ore bed. After R. P. Rothwell.

The ore itself is what is known as cerargyrite or chloride of silver, which, however, below true water level will change to the sulphuret of silver, with native silver in places. Of the latter change two indications have been met with. A tested sample yielded in a certain mine only 65 per cent of chloride of silver. This proportion will decrease in the ratio as water level is passed and the ore gets more outside of the reach of waters charged with oxygen and chloride of sodium. The grade of the camp is probably \$20 to \$25, though I have mined portions of beds which averaged right along \$35 to \$55, and others run as low as \$14 to \$17; and at times even \$8 and \$10.

We find in the same line of bedding strata holding petrifactions from 6 inches to 3 feet thick, which contain no silver ore, while above and below it silver is found in good permanent grades in strata showing a scarcity of vegetable remains. Again, I have seen a stratum where the upper 2 feet assayed about \$30, then 6 inches assaying \$100 or more, then 15 inches barren, and below it a layer of \$20 rock, all of the strata being full of petrifactions.

Another frequent occurrence is a foot or 2-foot seam of sandstone, full of petrifactions, charged with red oxide of copper, azurite, and malachite to some extent, and carrying no silver, while below it good paying ores were found free from copper, or in places barren rock. Such a copper cap has always been found a good indication for an ore body near by, and drifts which I started on this indication have since opened finely. As another matter of interest I found the seams, in which the vegetable remains are covered with autunite,[1] which is quite frequent around the Gad shaft, and the two carbonates of copper, unproductive, with pay seams, frequently above and below them.

As to the occurrence of copper in the silver bed I have observed a curious fact. If the copper present be azurite, or a grassy green looking malachite, the amount of silver in the bed will diminish, and it is a bad indication for the life of this particular shoot. If the copper presents, however, a pale but lively green, with a bluish shade in it, as we often find the stain on quartzy ores, it invariably improves the grade of the silver ore.

Other objects of interest in the beds are occasional pieces of vegetable matter changed into lignite, some of which will assay high in silver and others again be free from it. They are, in instances, coated with native silver and also intergrown in cases with pyrites, holding a very small amount of copper. In places trunks and branches of trees are found, some of which assay well, while others do not. The silver is not alone limited to the outside bark, but I tried pieces from the very interior of such branches, which I carefully washed and scrubbed, and they yielded as high as \$40 in silver. I also noticed, in the Buckeye Reef, a 6-inch seam of jasper, resting between sandstone and clay shale.

R. P. Rothwell[2] describes the occurrence of the ores as follows:

The silver occurs as chloride and sulphide and occasionally as native silver, disseminated through the more porous and fissured beds, and especially in the bedding and fracture planes of the sandstone, and coating the bright "slipped" surfaces of the hard shale beds—locally known as soapstone—where these beds have been disturbed and crushed. Wherever the shale is compact and has not been crushed—that is, wherever it remains in a condition in which water could not pass through it—it contains no silver. And wherever the sandstone beds become very hard, compact, and unfissured they appear to become poorer, and the silver is confined more largely to the bedding planes. The silver, that at some depth below the surface was distributed with more or less uniformity throughout the ore-bearing bed, appears to collect in the planes between the beds as these approach the outcrop, giving the appearance of the silver "vein," so called, having split up and come to the surface as thin leaders or stringers of very rich ore. This is not only the well-recognized condition of the silver-bearing beds everywhere near their outcrop, but it is the condition we should naturally expect from the mineral-bearing solution collecting in the bedding planes, as these offered more available channels near the surface.

It is quite evident that the silver we now find coating the polished surfaces of the crushed shales and filling the cracks and coating the surfaces of the fossilized (petrified) wood frequently found in the sandstone beds must have come there after these substances had assumed their present conditions. We may therefore expect to find in future, as has been found thus far, that the conditions which facilitate the percolation of the silver-bearing solution, where the rocks contained suitable precipitants, will favor the occurrence of ore, and the rocks becoming compact, hard, and unbroken—conditions which would naturally impede the percolation of water—will be found unfavorable to the occurrence of rich ore bodies.

The occurrence of ore in these sandstone beds is extremely capricious, as might be expected from the method of deposition suggested. It occurs in numerous chimneys or chutes, and has collected in portions of the beds where ferruginous or carbonaceous matter appears to have attracted it; yet copper, which in many places stains the rocks green, seems, on the contrary, to be an unfavorable indication for silver.

These ore chimneys are sometimes small and at other times they are several hundred feet in horizontal length in the bed. The ore at their limits—sometimes suddenly, sometimes gradually—disappears, while the sandstone bed frequently continues apparently undisturbed; in the former case it is generally noticed that the bed is crossed by a fissure, and it has sometimes been found that the ore, which up to the fissure impregnated one division of the bed, will pass up or down and continue beyond it in another part of the bed, or will pass completely into another bed. Consequently it is necessary to "cross-cut" quite frequently in prospecting in order to ascertain whether the ore which has disappeared from one bed may not be found in a neighboring one which at another point may have been quite barren.

The silver, though occurring chiefly in a few easily recognized beds in each reef, is by no means confined to these; in some of the mines it is found in paying quantities in only one, in other places in two, three, or four beds, while several of the other seams of sandstone contain small quantities or traces of the metal; and in those

[1] This mineral is possibly carnotite.

[2] The Silver Reef district, southern Utah: Eng. and Min. Jour., vol. 29, pp. 25, 26, 1880.

which, in certain divisions, carry paying quantities of silver, the balance of the bed too poor to be milled contains rich nodules and pockets of ore, and is broken up and sorted in the mines, producing an important part of the ore milled. It therefore happens that, while the dimensions of the rich portions of the bed may be small, perhaps 1, 2, or 3 feet, yet as much as 5 or 6 feet of intermediate or overlying poorer rock will contain sufficient rich ore in these nodules to make it profitable to break it down and sort it. This feature is observed in all the mines of the camp, and necessitates the exercise of judgment, guided by frequent assays, to estimate fairly the yield of ore in the reserves. It is evident that a sample taken over the entire thickness of rock which it pays to take down would give an assay so low as to make it appear worthless; yet perhaps one-third of the bed would give a high-grade ore, and the remaining two-thirds, yielding extremely rich ore in small iron-stained nodules and in plant impressions (which would be avoided in taking a sample), though apparently of little value, will, in reality, yield nearly as much silver as the one-third from which we obtained a good assay.

In the Last Chance mine, and also in the Buckeye mine, are places where it pays to mine out the bed to the height of 10 to 14 feet; yet a sample of this entire thickness would give so low a return that the whole bed would be rejected. Nevertheless, by the exercise of skill in sorting the ore, a large amount of good ore is obtained from portions of the bed which, according to the sample, would be worthless. Indeed, for this reason it is found that the sample assays in all of these mines run much below the actual mill returns from the same ore.

For the reasons already stated, the ore chimneys seem almost as capricious in their vertical as in their horizontal dimensions. Nevertheless, where exploration has been continued, either in depth or horizontally, other chutes or chimneys have generally been found within a short distance. As none of the mines have exceeded a few hundred feet in vertical depth (the deepest mine in the district extends 600 or 800 feet on the bed from the outcrop to the deepest point opened—a vertical depth below the surface of perhaps 200 feet), the question of the continuation or recurrence of ore bodies at a great depth is an open one. No data sufficient to base an authoritative opinion on having yet been afforded, though the past experience seems to prove that no depth yet attained has exercised any injurious influence upon the richness of the ore.

The work already done on the silver-bearing reefs has fully demonstrated that the ore is more abundant and richer at certain points than at others, and a most careful examination of each particular property is necessary to determine its value; for while the rocks which contain the ore are as continuous as other sedimentary beds, the occurrence of pay in them appears to be subject to the same laws, conditions, and accidents which have governed the deposition of similar ores in fissure veins.

The following description of the occurrence of ores in the Barbee and Walker mines by W. M. Nesbit is given by Jenney:[1]

Watson M. Nesbit, who was connected with mining operations at Silver Reef from 1878 to 1888, gives the author the following statement of the manner of occurrence of the ore: In the Barbee and Walker mine, water was struck at a depth of about 500 feet vertically. Near that point the ore changed in appearance and character, and gave great trouble in amalgamation, the extraction being very low. The ore was treated hot, in pans; a thick scum rose on the pans, like heavy petroleum oil, and had to be removed from time to time during the amalgamation. From a charge of $1\frac{1}{2}$ tons of ore, as much as a gallon of this oily material would be obtained. The ore at water level, if carefully stoped, averaged 12 to 16 ounces of silver per ton; but only a part of the silver could be saved in pans. A very little pyrite appeared at water level—the first seen in the mines. About 100 to 200 feet above water level, on the slope of the beds, the ore was in places very rich; and small bunches of lignite coal, 4 to 10 inches across, were found embedded in the soft sandstone, with native silver deposited in thin scales on the joints of the coal. Most of the ore at this depth was silver sulphide. At one place a tree trunk, 18 inches in diameter, was found; the heartwood was silicified and very hard, and carried 8 to 10 ounces of silver per ton. The sapwood and bark, 3 to 6 inches in thickness, were altered to soft, crumbling lignite, full of silver sulphide; it assayed 5,000 ounces of silver per ton. The ores from the Silver Reef mines never showed any gold by assay; but in leaching the ore by the Russell process, the silver sulphides produced contained a trace of gold.

MINERALOGY.

The mineralogy of the ores is relatively simple. In the upper parts of the ore bodies practically all the silver is in the chloride, cerargyrite (horn silver). Some parts of the reefs, especially of the East Reef, contain copper carbonates in small amounts; Mr. Rolker reports autunite in the Gad shaft; and the writer found a small amount of a yellow uranium-vanadium mineral that resembles carnotite. Mr. Don Maguire has kindly furnished the writer with a specimen from the Buckeye Reef, containing a yellow uranium mineral together with blue and green carbonates of copper. D. B. Huntley also reports the presence of a uranium mineral from the Tecumseh mine, as follows:[2]

The following peculiar action of the bullion was noticed in this district, and especially at the Christy mill, when working on some Tecumseh ore, which contained a number of minute yellow specks. After the bullion was poured from the pot into the mold and had apparently solidified, it would begin to swell (not sprout) and rise slowly in the mold until the spongy surface was from 3 to 4 inches above the first surface. The melter noticed that this action was

[1] Jenney, W. P., The chemistry of ore deposits: Am. Inst. Min. Eng. Trans., vol. 33, p. 464, 1902.

[2] Huntley, D. B., Tenth Census U. S., vol. 13, p. 481, 1885.

prevented, or at least diminished, by keeping the molten silver in the pot a considerable time before pouring. A person said to be connected with the laboratory of Hamilton College, New York, while visiting at Silver Reef, took some samples of these yellow ores, and, on returning to the East, reported that they contained phosphate of uranium. This statement has not been authenticated, but is given for what it may be worth.

Hydrous iron oxide is rather uniformly present with the silver ores and is abundant in many of the richer ones.

It is commonly reported that below water level both the silver and copper are present mainly as sulphides, with a little native silver. Newberry,[1] however, states that the average of four analyses of silver ores showed 0.23 per cent of selenium and 0.26 per cent of silver, which would suggest that part of the silver at least may be combined in some form with selenium. The abundance of hydrous iron oxides in the oxidized ores indicates some iron in the unoxidized ores.

It seems to be the general experience of all who worked in the district that abundant copper indicates relatively low silver content. Rolker's statement, however, seems to indicate some exceptions to this rule.

EXTENT AND DEPTH.

The important mineralization thus far discovered is within about 2 miles of the northern end of the reefs. The same formations can be followed for many miles southward, and it is reported that at numerous localities a low content of silver has been found, though nowhere sufficient to be of economic importance. Newberry states that sandstones at essentially the same horizon in the vicinity of Cedar City contain silver. The most promising locality next to the Leeds district seems to be in the vicinity of Virgin City on North Creek. This locality was not visited and no description has been found in the literature, but from common report the occurrence is apparently similar to that at Silver Reef.

The maximum distance on the incline to which the ore beds have been followed is about 1,000 feet, in the Maggie, California, and Tecumseh, on the Buckeye Reef. At that distance from the outcrop the beds are little more than 150 feet vertically below the surface.[2] On the Thompson and McNally claims, on the White Reef, vertical depths of 245 feet were attained at a distance of 560 feet on the incline outcrop.[3]

No detailed information as to the relative output from different depths on the reefs is available, but it is probably safe to say that by far the greater part of the silver came from within 500 feet of the outcrop and within 150 feet of the surface.

On the Buckeye Reef water was reached in some of the mines a few feet below the surface, and it is reported that in wet seasons the shafts are filled with water to the surface. The flow of water, however, does not seem to have been great.

The failure to follow the ores to greater depths is not readily explainable at this late date. It is variously ascribed to the refractory character of the ores; to the added costs of work and of pumping at increased depth; and to a decrease in silver content. Though each of these factors doubtless increased the cost of production it seems reasonably certain that a material decrease in the silver content at depth was the main cause for the abandonment of the deeper workings.

The principal mines on the different reefs in 1880 were given by Huntley [4] as follows from north to south:

White Reef: Barbee & Walker, Pinkham and Dodge, Leeds, Thompson and McNally, and Gisborn.

Buckeye Reef: Silver Flat, Manhattan, Tecumseh, Kinner, Buckeye, Last Chance, Maggie, California, and Emily Jane.

East Reef: Vanderbilt, Duffin, Dykes & Stopeley, Toquerville, Maud, and Dixie.

TENOR OF ORES.

The grade of the ore extracted has depended on the possibility of profitable treatment. In the early days, when the ores were shipped to Salt Lake or Pioche, only very high grade material could be profitably mined. Later a much lower grade was treated in the district. The Director of the Mint stated [5] in 1882 that for the three and one-half preceding years the Stormont Silver Mining Co. milled about

[1] Eng. and Min. Jour., vol. 31, p. 5, 1881.
[2] Director of the Mint Ann. Rept. for 1882, p. 269, 1883.
[3] Idem, p. 269.
[4] Huntley, D. B., Tenth Census U. S., vol. 13, p. 479, 1884.
[5] Director of the Mint Ann. Rept. for 1882, p. 269, 1883.

50,000 tons of ore averaging 22 ounces of silver per ton, and that in five years the Christy Mining & Milling Co. treated 55,000 to 60,000 tons, yielding an average of 27.75 ounces. Later, ore yielding as low as 10 ounces per ton was milled, but the average was probably considerably above that.

GENESIS.

The origin of the ores in the sandstones has long been discussed, but as yet no general agreement concerning them has been reached. The Silver Reef deposits are the most important of the type in this country, and about 1880 their origin was vigorously argued. Two ideas were advanced, one that they were deposited from gaseous or watery solutions given off by igneous rocks, and the other that they were precipitated, while the sandstones were being formed, by decaying vegetable matter, from the water of a shallow sea. More recently another idea has been advanced—that the metals were originally deposited with the sediments, probably largely as eroded mineral fragments from veins, and were later dissolved and reprecipitated in a more concentrated form by circulating waters.[1] Lindgren also considers that the first deposits were argentiferous chalcocite and that the silver ores have resulted from a reworking of these deposits.

The relation of these deposits to the Leeds anticline leaves small room for doubt that they were deposited after the formation of this structure in Tertiary time. It is, of course, possible to suppose that the relation is accidental, but this does not seem likely. If this relation to the structure is granted, the ores were not formed till Tertiary time, and, of course, the idea that they were deposited with the sediments in Triassic time is untenable.

Whether the metals were deposited from solutions given off from an igneous magma or concentrated from material deposited with the sediments is not so easily determined. Very pronounced volcanic activity took place about the time of the folding of the strata in Tertiary time. Further, an igneous body has apparently been intruded on the line of the northward extension of the Leeds anticline, a few miles north of the point where the ore-bearing reefs pass below the present surface.[2] (See Pl. XLVI.) Solutions given off by such bodies might readily work upward through the porous sandstone strata along the crest of the anticline and deposit their metal load as they reached areas of less heat and pressure or reacted with the carbonaceous or other material in the sandstone. The ores contain selenium, as do also the silver, gold, and mercury ores in the Marysvale district, where, with much greater certainty they may be attributed to an igneous origin. Selenium is, however, common in the sandstone ores of the Plateau region.

On the other hand, it is reported, apparently reliably, that the sandstones at this horizon contain small amounts of silver over large areas, and it is also known that they carry gold. (See p. 634.) If at the time of the uplift and folding of the region, or later, a circulation was set up that centered along the crest of the anticline, the metal might readily have been concentrated to the existing extent.

Possibly, as suggested by Lindgren, enrichment has been an important factor in forming the ores from argentiferous chalcocite, but the writer has failed to find much evidence of it. Rich ores were found at the surface, and migration of silver seems to be unimportant. If enrichment were due to the precipitation of silver or silver sulphide on copper sulphide ores carrying both copper and silver would probably be found; the presence of copper, however, is said to indicate low silver content.

If the ores are related to the structure they were deposited near the summit of the anticline and for only a few hundred feet down either limb; and if several hundred feet of the ore-bearing beds were removed from the summit of the anticline little if any ore would remain. This may explain the absence of ore in the sandstone south of Harrisburg and Virgin River, where several hundred feet of the "reefs" have been eroded from the summit of the anticline.

FUTURE OF THE DISTRICT.

Operations in the district are now (1917) practically abandoned and for many years only small operations have been carried on by lessees (chloriders). Most of the high-grade ore in the known ore-bearing territory above water level has certainly been extracted. It is com-

[1] Lindgren, Waldemar, Mineral deposits, p. 368, New York, 1913.

[2] Huntington, Ellsworth, and Goldthwait, J. W., op. cit., p. 218.

monly stated, however, by those familiar with the mines that a rather large quantity of rock containing 5 to 12 ounces of silver per ton remains in the old workings and on the dumps. If such ore exists it will doubtless be treated at some time, and if sufficiently abundant it could be done at relatively low cost, for electric power could be generated on Virgin River, and farm produce is not excessively high.

The northward extension of the reefs, where they pass beneath the present surface and form the roof of the Leeds anticline, seems to be the most promising area for new prospecting.

Uranium minerals were seen in but small quantity in the district. This, however, may have been due to failure to examine proper places or to lack of familiarity with this class of ore when the district was visited. Future operators should keep in mind the possibility of finding uranium in commercial quantities.

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SANTA CLARA DISTRICT.

The Santa Clara district, in Washington County, is 10 miles west of St. George. The sandstone strata of the Silver Reef district are present in this district and were the basis of prospecting. It was organized in the spring of 1880. Around St. George and between it and Silver Reef there are several districts, Volcanic, Gunlock, and others, that cover miles of sandstone country and contain many locations. Little work, however, has been done in them and no ore has been shipped.[1]

BEAVER DAM MOUNTAINS.

By B. S. Butler.

GENERAL FEATURES.

The Beaver Dam Mountains, in the southwestern part of Washington County, trend in general northward from Colorado River as a well-defined range for about 20 miles to a low pass, beyond which a less well-defined portion extends several miles farther. The range is generally from 4,000 to 5,000 feet high but in places attains a maximum elevation of about 7,000 feet. Water is scarce, there being no perennial streams and but few springs. There is no timber on the range suitable for building, but a growth of "cedar" (juniper) and other scrubby trees serves for fuel and can be used for mine timbering to some extent.

GEOLOGY.

The rocks in the mountains range in age from pre-Cambrian to Triassic. Except for pegmatitic dikes in the schists on the west side of the range and extrusive flows and a few dikes in the Bull Valley region, they are of sedimentary origin.

SEDIMENTARY ROCKS.

The sedimentary series apparently corresponds closely with that studied by Gilbert at the mouth of the Grand Canyon.[2] (See Pl. VI.)

The lowest rocks exposed where the old Overland trail crosses the Beaver Dam Mountains are mica and hornblende schists cut by pegmatitic dikes. The schist is overlain by several hundred feet of red quartzite containing beds of fine conglomerate, and this in turn is overlain by several hundred feet of sandy shale, sandstone, and arenaceous limestone. Next above lies heavy-bedded blue limestones and heavy-bedded gray limestones, each esti-

[1] Precious metals: Tenth Census U. S., vol. 13, p. 483, 1885.

[2] U. S. Geog. and Geol. Survey W. 100th Mer., Rept., vol. 3, pt. 1, p. 196, 1875.

mated to be 600 to 800 feet thick. Overlying the gray limestones are thinner-bedded limestones overlain by sandstones. The rocks seem to correspond with Gilbert's section essentially as follows: The quartzite and conglomerate overlying the schists and the shaly sandstone series belong to the Tonto group. The great series of limestones limited upward by the sandstone series are apparently to be correlated with the Redwall limestone; and the upper sandstone series belongs with the Aubrey group.

Fossils were collected from the limestones in which the Dixie and other mines of the Tutsagubet district have been developed, and from the limestone in the Bull Valley gold district in the northern extension of the range. G. H. Girty assigns both collections to the Pennsylvanian, though he states that they show some unusual features. In the collection from the Tutsagubet district he determines the following forms:

Derbya crassa.
Productus arkansanus?
Productus cora.
Spirifer rockymontanus.
Phillipsia sp.

In the collection from Bull Valley he determines the following:

Schizophoria resupinoides.
Marginifera splendens.
Productus punctatus.
Spirifer cameratus.
Spirifer rockymontanus.
Productus aff. P. wallacianus.

IGNEOUS ROCKS.

The only igneous rocks observed in the southern part of the range were pegmatite dikes, which are rather plentiful in the small area of schists that was examined. The dikes are rather coarse grained and are composed essentially of quartz, pink feldspar, and a relatively small amount of muscovite. They were not observed cutting the sedimentary series and are probably older than the basal quartzite.

In the northern extension of the range igneous rocks are abundant. In the Bull Valley iron district both intrusive and extrusive rocks are abundant. (See p. 581.) Near the Bull Valley gold district extrusive rocks prevail north and west of the district. They are porphyritic in character and many of them contain rather numerous phenocrysts of quartz, biotite, orthoclase, and plagioclase. Quartz and biotite are rather variable in amount; quartz is nearly wanting in some rocks and biotite is present in only small amount in others. A large part of these rocks are probably quartz latites, though some flows are probably true rhyolite and others may properly be classed as andesite. Dikes in the sedimentary series were noted especially in the canyon of the East Fork of Beaver Dam Wash; they are usually highly altered but are apparently of moderately basic composition.

STRUCTURE.

The sedimentary rocks of the district strike in general north and dip east at a rather low angle. The range, which is apparently to be classed with the basin range type, has evidently resulted from faulting along its western face and from relative uplift and easterly tilting. Minor faulting and fissuring has furnished channels for the solutions that formed the ore deposits.

TUTSAGUBET DISTRICT.

The Tutsagubet district is near the central portion of the Beaver Dam Range, about 14 miles nearly due west from St. George and about 60 miles southeast of Acoma, Nev., the nearest railroad point on the Los Angeles & Salt Lake Railroad.

HISTORY AND PRODUCTION.

By V. C. Heikes.

Tutsagubet district, in Washington County, organized June 2, 1883, was first mentioned by Raymond,[1] who refers to it in 1872 as the St. George district, in which no claims had been opened or worked up to April, 1871, though many locations had been made. Later Raymond[2] reports that in 1875 a furnace was erected near St. George on Virgin River for the treatment of copper ore from the Grand Gulch mine, in the Bentley district, Mohave County, Ariz., 129 miles south of St. George. The furnace was abandoned shortly after its completion, and there is no record of its having reduced any ore from the district.

[1] Raymond, R. W., Statistics of mines and mining in the States and Territories west of the Rocky Mountains for 1871, p. 329, 1873.
[2] Idem for 1875, p. 281, 1877.

In 1884 the Mountain Chief Mining Co. built a one-stack furnace on Virgin River to reduce lead carbonate ores said[1] to assay 65 per cent of lead and 15 ounces of silver. Charcoal was used for fuel and smelting begun November 8, 1884. In September, 1885, the company was in litigation and the property closed. The amount of lead bullion produced is not known. Between 1884 and 1888 the Apex or Dixie Copper mine, first known as the Pen mine, was worked, and is reported[2] to have shipped 300 tons of copper ore, largely carbonate, out of the district. S. R. Callaway,[3] superintendent of the Dixie mine between 1889 and 1893, reports that the company received about $300,000 for ore and bullion shipped to Swansea, Wales, and to Denver, Colo. In May, 1891, 13 tons shipped out of the district from a new find assayed copper, 54.2 per cent; sulphur, 4.1 per cent; iron, 5.7 per cent; silica, 2.6 per cent; and silver, 4 ounces. At the time it cost $30 per ton to ship by wagon, 154 miles to Milford, the nearest railroad point. In 1899 a small furnace at St. George produced 8 to 20 tons of blister copper per month from ore containing 15 per cent of copper with charcoal and coke fuel. Coke cost $27 per ton at the smelter. In November, 1900, another but larger furnace at Shem, 12 miles northwest of St. George, produced 3 to 4 tons of bullion daily from ore containing 10 to 15 per cent of copper. This small smelter operated intermittently under several managements until 1907. The copper bullion produced in 1901 averaged between 89 and 91 per cent of copper and 14 and 21 ounces of silver per ton; some of that produced several years later carried 93 per cent of copper and 5 to 6 ounces of silver per ton. Occasional lots of matte assayed about 74 per cent of copper and 7 ounces of silver. The last production of the district was a small lot of copper ore shipped to one of the Salt Lake smelters in 1909.

[1] Eng. and Min. Jour., Oct. 18, p. 272, 1884.
[2] Eng. and Min. Jour., Mar. 21, 1891.
[3] Personal interview, 1914.

Metals produced in Tutsagubet district, 1887–1917.

Period.	Gold.		Silver.		Copper.		Lead.		Total value.[a]
	Fine ounces.	Value.	Fine ounces.	Value.	Pounds.	Value.	Pounds.	Value.	
Prior to 1887	1.35	$28	[b] 1,200	$1,176	[b] 300,000	$41,400	([c])	....	$42,576
1890–1894 [d]	....	....	18,562	15,786	1,784,065	209,606	....	....	225,392
1898–1909 [e]	....	....	124,426	74,735	8,318,266	1,233,570	43,669	$2,315	1,310,648
1914–1917	0.18	4	667	388	192,735	48,540	....	....	48,932
	1.53	32	144,855	92,085	10,595,066	1,533,116	43,669	2,315	1,627,548

[a] Includes gold worth $28.
[b] Estimated from 300 tons of copper ore said to have been produced.
[c] Lead unknown.
[d] Figures of metal production largely taken from Director of Mint reports. No ore tonnage given.
[e] From 1902 to 1909 the reports of producers were used; prior to 1902 the production is partly estimated through reliable sources.

ORE DEPOSITS.

All the ores are replacement deposits in limestone adjacent to fissures.

COPPER DEPOSITS.

The Dixie mine of the Utah & Eastern Copper Co. is the most important in the district. At the time of visit, in October, 1911, the mine workings were not accessible, and the following notes are based on such observations as could be made on the surface and descriptions by those familiar with the mine. At the surface the deposit appears to be associated with a fissure striking in general northeast and dipping about 45° SW. At depth, however, it is stated that the association of the deposit with a fissure is not apparent. The ore is said to occur in an irregular chimney.

The deposit has been developed by a tunnel intersecting the ore body about 125 feet below the outcrop and by a second tunnel about 180 feet below the first. A winze sunk from the tunnel is said to have attained a depth of 900 feet with another winze 100 feet below that level.

It is reported that all the ore from the mine was oxidized, not even remnants of sulphide being found. Rather abundant jarosite, how-

ever, and more complex sulphates indicate that sulphides must have been present in the original ores, perhaps as both iron and copper sulphides or as an iron-copper sulphide. The copper minerals are said to be principally the carbonates, azurite and malachite, and also cuprite and to a less extent some complex sulphates and phosphates of copper, iron, and lead. Some lead occurred as the carbonate cerusite, the sulphate plumbojarosite, and other complex sulphates. Iron oxide is relatively abundant, as indicated by the dump. Unreplaced and silicified limestone are the principal nonmetallic materials. The ore extracted probably yielded approximately 12 per cent copper and 1.5 ounces silver per ton.

The developments of the Superior mine are in a northwest-southeast fault zone, in which the limestone has been highly brecciated. The ore occurs as irregular masses through the breccia. The copper minerals are principally carbonates and a little silicate, in a gangue of brecciated limestone with numerous veinlets of calcite.

LEAD-SILVER DEPOSITS.

The Paymaster mine, a short distance south of the Dixie mine, has been developed along a northwest fissure. The ore forms irregular bodies in the limestone adjacent to the fissure. There has been several hundred feet of development work, but no important bodies of ore have been found, though large bodies of oxidized iron ore are said to have been encountered. Ore on the dump contained the carbonate of lead, cerusite; the sulphate of lead and iron, plumbojarosite; and the basic iron sulphate, jarosite. A small smelter erected to treat the ores from the mine was never successfully operated.

In the Black Warrior mine the ore deposits are associated with an extensive cave, which extends from the surface downward on a gentle dip for more than 200 feet along a fissure or fault where the limestone was considerably crushed. When discovered the cave was thickly studded with stalagmites, stalactites, and columns of calcite, and the floor was littered with fallen blocks of limestone. The ore was found in fissures in the sides and top of the cave and beneath the blocks of limestone. The ore is said to have been silver-bearing cerusite and was of high grade. Abundant limonite has apparently resulted in part at least from the oxidation of an iron-bearing carbonate and possibly in part from iron sulphide. Little development had been done at the time of the writer's visit aside from following the ore bodies that opened into the cave.

The original metallic sulphides, together with some iron-bearing carbonate, may have replaced limestone adjacent to a fissure. Later, surface solutions descended along the fissure, oxidized the ores, and dissolved and carried away a considerable amount of the limestone, forming the cave. Still later, solutions laden with lime carbonate entered the cave and deposited part of their load as stalagmites, stalactites, and columns.

A little prospecting has been done and some ore found in numerous other claims in the district, but in general it has not been sufficient to encourage extensive development under present conditions.

BULL VALLEY (GOLDSTRIKE) DISTRICT.

GENERAL FEATURES.

The Bull Valley or Goldstrike district is in the western part of Washington County, near the Nevada line. The nearest railroad point is Modena, on the Los Angeles & Salt Lake Railroad. A small stream in Bull Valley is said to furnish a supply of water throughout the year. A rather scanty growth of cedar and other scrubby trees affords fuel and some mine timber.

The finding of specimens of rich gold rock has caused one or two gold excitements in Bull Valley, but to the close of 1913 the gold production had been limited to such specimens. In 1914 and 1915 developments were active, a mill was erected, and it is reported that some gold was produced.

GEOLOGY.

The sedimentary rocks of the district comprise a series of limestones with interbedded quartzite and some shale. The extrusive rocks in the southern part of the district are latite and rhyolitic flows and some more basic rocks. Dikes and small sills of intrusive rock cut the sedimentary rocks and are especially well exposed in the canyon of the east fork of Beaver Dam Wash.

ORE DEPOSITS.

DEVELOPMENT.

All the mineral deposits noted in the district at the time of the writer's visit have been formed by replacement of the sedimentary

rocks, and, so far as known, the gold deposits since explored have a similar origin. The deposits that have received attention in the southern part of the district are chiefly of gold, though antimony and arsenic deposits have been slightly prospected.

GOLD DEPOSITS.

The few gold deposits exposed in the district at the time of the writer's visit were in sedimentary rocks along fissures. The sediments adjacent to the fissures are highly silicified. Quartz and carbonate are the main nonmetallic minerals. The outcrops are stained yellow and brown with iron. A specimen of vein material examined under the microscope showed the presence of a yellow mineral resembling jarosite. This mineral could not be separated in the specimen collected, but a test showed the presence of sulphate, and the mineral is doubtless jarosite or some closely allied mineral. The gold occurs free so far as determined.

A specimen of high-grade ore (Pl. XLIX) from some distance below the surface, presented to the National Museum by M. R. Evans, contains native gold in a carbonate gangue. The carbonate is in part calcite and in part a light-brown mineral that contains iron and probably some manganese. The gold occurs as thin leaves in minute fissures in the carbonate along cleavages in and between mineral grains. In the specimen the gold is most abundantly associated with the brown carbonate, though occurring also in the calcite. Qualitative tests of the brown carbonate showed iron and a little manganese. The sheets of gold have a beautiful pitted surface corresponding to the etched surfaces of the carbonate crystals. This appears from descriptions to be its normal occurrence in rich pockets.

The sulphates in the ore deposits suggest that the original minerals were, in part at least, sulphides. The association of the gold with ferric sulphate suggests a similarity to the gold-platinum-palladium deposits of southern Nevada, which Knopf [1] thinks have resulted from enrichment of the leaner sulphides.

The occurrence of the gold replacing the carbonate associated with limonite and manganese is also sufficiently suggestive of enrichment, so that operators should keep the idea in mind in development.

ARSENIC DEPOSITS.

The arsenic deposit occurs in sandy sediments in a breccia zone that outcrops in the bed of Arsenic Canyon, where the stream has swept away the débris. The arsenic sulphide forms irregular areas surrounded by quartz, giving the rock an amygdaloidal appearance. Much of the quartz has a distinct crystal outline, and surrounds rosettes of fibrous material of distinctly lower index, from which it appears to have been derived. (See Pl. XLVIII.) As seen in thin section the fibrous mineral is light brown and contains few inclusions. The quartz, on the other hand, is colorless and contains abundant inclusions of a mineral of rather high index and birefringence and, apparently, extinction parallel to the elongation. It contains also abundant dark inclusions and some gas cavities, a small proportion of which inclose liquid. A small cube was noted in one such cavity. The relations suggest that in the fibrous chalcedonic mineral the materials that form the inclusions in the quartz are dissolved in the silica.

The principal metallic mineral of the deposit is the red sulphide of arsenic, realgar, which, on exposure to the weather, appears to alter to the yellow sulphide, orpiment.

Practically no development work has been done on the deposit at the time of visit.

ANTIMONY DEPOSITS.

Antimony is said to occur in at least two localities. A prospect a few hundred yards northeast of the gold prospect of R. G. McQuarrie consists of a body of stibnite 6 to 12 inches thick, which has been uncovered for a distance of about 6 feet. It appears to be a flat-lying deposit near the contact of limestone and quartzite, the sandy sediments underlying and the limestone overlying. Antimony is also reported from farther northeast.

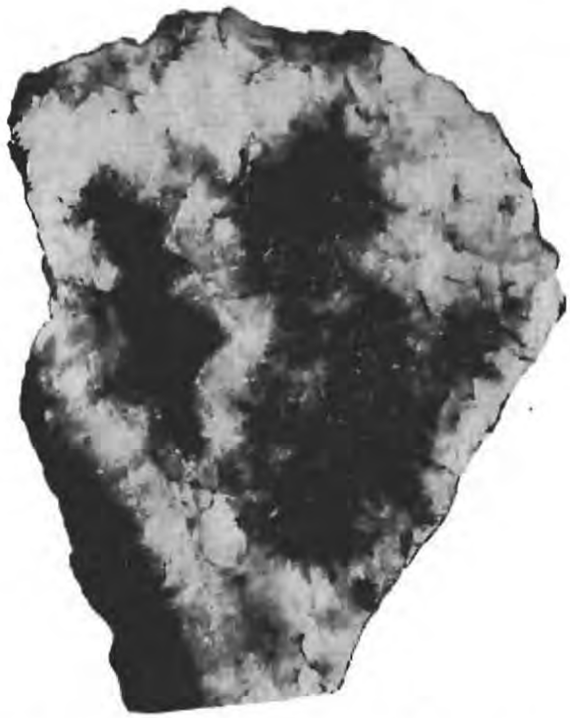
IRON DEPOSITS.

The iron deposits in the northern part of the district are discussed on page 581.

[1] Knopf, Adolph, A gold-platinum-palladium lode in southern Nevada: U. S. Geol. Survey Bull. 620, pp. 1-18, 1915.

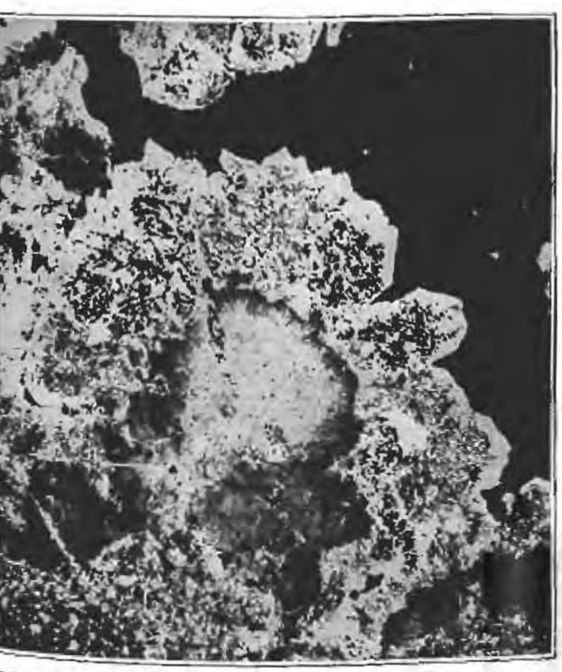
. SPECIMEN OF NATIVE GOLD IN CARBONATE GANGUE FROM THE BULL VALLEY DISTRICT.

U. S. Nat. Mus. No. 88457. Enlarged one-half.



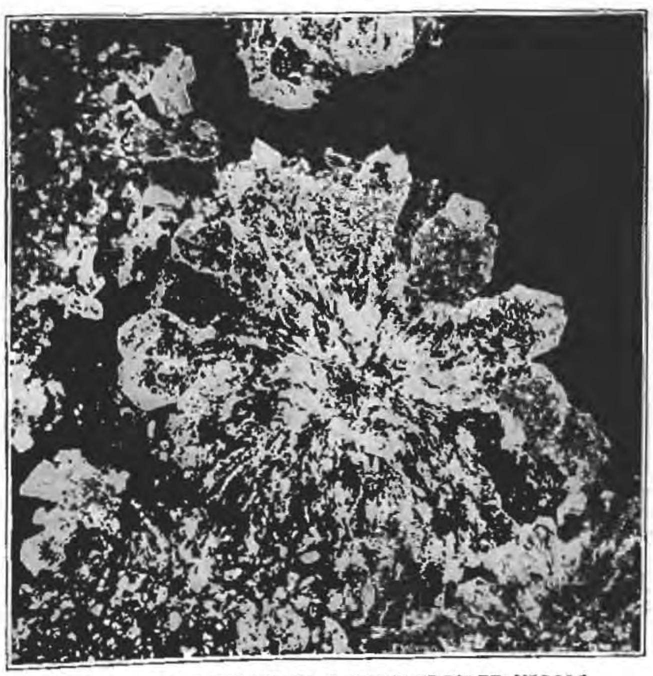
B. POLISHED SURFACE OF SPECIMEN SHOWN IN *A.*

Veinlets of metallic gold; dark areas, brown carbonate containing a little limonite. Enlarged 4 diameters.



IOTOMICROGRAPH SHOWING ROSETTE OF QUARTZ SPECIMEN OF ARSENIC ORES FROM BULL VALLEY TRICT.

k areas, realgar; light areas, quartz. Enlarged 30 diameters.



D. SPECIMEN SHOWN IN *C*, WITH CROSSED NICOLS.

Enlarged 30 diameters.

UINTA MOUNTAINS.

By B. S. Butler.

INTRODUCTION.

The Uinta Mountains have yielded relatively small amounts of metals and have therefore been little studied by the writer in preparation for this paper. In September, 1913, he spent two days in a trip from Vernal to the Dyer mine, and the same month he and F. L. Hess visited prospects in the vicinity of Browns Park. The following statements concerning the geology of the range are largely a compilation.

PHYSIOGRAPHY.

The Uinta Range extends from the Wasatch Range in the northeastern part of Utah eastward into Colorado, a distance of about 150 miles, with an average width of approximately 35 miles. Its glacial features have been described in detail by Atwood,[1] and its topography and physiography have been summarized by Boutwell[2] as follows:

The general form of the range is an elongated, broad, flat-topped arch. As the main east-west divide lies north of the center of the range, a north-south profile shows unsymmetrical slopes. The northern slopes fall off steeply to a great undulating basin, while the southern slopes descend very gently to an extensive plateau region. The elevation of the range varies from 6,500 feet in its western foothills, where it dips under Kamas Prairie, to 12,400 on Mount Agassiz, 12,500 on Hayden Peak, 13,200 on Mount Tokewana, 13,250 on Mount Lovenia, and 13,486 (corrected) on Emmons Peak.

An oval central area is encircled by a series of generally continuous, unsymmetrical ridges, with steep inward-facing scarps and more gentle outfacing slopes. Dissection has reduced the inclosed interior plateau to a region of strong relief characterized by an exceedingly narrow steep-sided main east-west divide, which rises into isolated peaks and falls off steeply to the north and south to heads of great canyons. These canyons, especially those draining to the south, are characterized by broad, flaring, high-lying upper levels, deeply trenched by very narrow steep-sided gorges. In the western part of the range some of these headward portions, on emerging from the interior area, continue north or south along radial courses through the encircling ridges and down their gentle outfacing slopes. Others on reaching these ridges turn abruptly and escape by longitudinal valleys, whose alluvial bottoms are terraced and trenched. A third class of streams, which are characteristically short and not graded, head near the crests of these encircling ridges and flow down infacing scarps toward the interior of the area (opposite to the direction of prevailing dip), thence out by the longitudinal valleys. In the eastern part of the range the drainage departs from these simple types. Thus, in different parts of its course, Green River exhibits characteristics of several different types of drainage. In the extreme western portion of the range Provo and Weber rivers, the master streams of the region, pursue longitudinal courses for a large portion of their extent. They are fed not only by headwaters of transverse radial streams but also by streams flowing toward the interior against the dip.

In brief, the range is an elongated dome composed of a deeply dissected central plateau and encircling cuestas. The dissection of the central area is characterized by a postmature master divide, surmounting broad glacial amphitheaters, which in turn are incised by deep, narrow canyons. Intermediate between the eastern and western portions of the range the drainage is largely consequent; at the eastern end it is complex, Green River probably being superimposed, locally at least, and in the western portion the master streams follow partially graded, subsequent courses, and obsequent drainage is well developed.

Since this description was prepared a paper by Schultz[3] on the Uinta Mountains, with special reference to phosphate, has been published.

A feature of the physiography that is of interest, as it is of widespread occurrence in eastern Utah, is the high gravel-capped plateau or bench that is strongly developed on both the north and south sides of the range at its eastern end at least. Rich[4] has described its occurrence on the north side, where its elevation is 7,600 to 8,500 feet. On the south side, in the longitude of Vernal, its elevation ranges from about 8,000 feet at its outer edge to about 9,000 feet where it merges with the old mountain topography of the central portion of the range. Farther east it may be somewhat lower. Split Mountain and the Yampa Plateau are concordant in elevation with this plateau surface and are evidently to be correlated with it.

The top of the plateau is an old erosion surface that slopes gently from the mountain and has beveled all the formations regardless of hardness or position. Near the central mountain mass the more resistant strata form low ridges that alternate with longitudinal valleys cut in the softer rock. This surface in the eastern part of the range has been covered by a mantle of coarse gravel composed largely of pebbles and boulders of red sandstone (probably the Bishop Mountain conglomerate of Powell) derived from the central portion of the range. Near its outer margin the plateau is cut by deep canyons, but few of them reach completely across the plateau, so that

[1] Atwood, W. W., Glaciation in the Uinta and Wasatch mountains: U. S. Geol. Survey Prof. Paper 61, 1909.

[2] Boutwell, J. M., Iron ores of the Uinta Mountains, Utah: U. S. Geol. Survey Bull. 225, pp. 221-228, 1904.

[3] Schultz, A. R., A geologic reconnaissance of the Uinta Mountains, northern Utah, with special reference to phosphate: U. S. Geol. Survey Bull. 690, pp. 31-94, 1919.

[4] Rich, J. L., The physiography of the Bishop conglomerate, southwestern Wyoming: Jour. Geology, vol. 18, p. 601, 1910.

east-west travel along the base of the range is comparatively easy whereas along the front of the plateau it is practically impossible. At several lower levels other gravel-covered benches or mesas strongly suggest periods of erosion followed by uplifts that allowed further deepening of the stream beds. These benches, however, were not examined in sufficient detail to warrant an attempt to explain them, but they afford an interesting problem in the physiographic development of the region.

A similar plateau in the western portion of the range has not been described, though inspection of the topographic maps suggest its presence.

GEOLOGY.

SEDIMENTARY ROCKS.

The sedimentary formations of the Uinta Mountains range in age from Archean to Recent, but their satisfactory classification must wait for detailed geologic work. Several reconnaissance studies have grouped the formations in a general way. The most recent classification is that by Weeks.[1]

Unconformably underlying the "Uinta formation," as described by Weeks, is Powell's Red Creek quartzite,[2] presumably of Archean age, which consists of mica, hornblende, staurolite, and garnet schists with beds of white quartzite. This quartzite is exposed on the north side of Browns Park for several miles east and west of Red Creek Canyon, including Red Creek, Jessie Ewing, and Willow Creek canyons, where there has been considerable prospecting in it.

The great quartzite series of the Wasatch Range has already been subdivided and detailed study will probably result in the subdivision of the stratigraphically corresponding great red quartzite series in the "Uinta formation." It is also probable that the limestone members will be further subdivided.

Generalized Paleozoic section in the Uinta Range.

[By F. B. Weeks.]

Formation.	Character.	Thickness.	Age.
Permo-Carboniferous	Red shales — *Feet.* 860; Light-gray sandstones — 1,050; Red shales and dark-blue limestones — 660	*Feet.* 2,570	Permian.
Weber formation	Yellow calcareous sandstone; white and gray quartzite, weathering brown.	2,200 to 2,700	Pennsylvanian.
Mississippian series (upper part Pennsylvanian series).	Alternating beds of white sandstone; thin-bedded blue and gray cherty limestones and massive dark-green and buff limestones at base.	700 to 1,070	Mississippian.
Ogden quartzite	White and greenish massive quartzite and green sandstones with interbedded conglomerates.	0 to 1,100	Ordovician.
Lodore shales	Argillaceous and sandy, green, red, purple, and black shales; green shales, containing many nodules.	530 to 1,200	Cambrian.
"Uinta" formation	Thin-bedded green sandstones with conglomerate layers; striped quartzites; and red and brown quartzites or sandstones. Base not exposed.	12,000+	Pre-Cambrian.

Overlying the Paleozoic section as given by Weeks are the Jurassic and Triassic sandstones and shales with beds of limestone having a total thickness of over 5,000 feet, according to Powell. These are overlain by 36,000 feet of Cretaceous sandstones and shales, and these in turn by 20,000 feet of Tertiary sandstones and shales.

IGNEOUS ROCKS.

So far as the writer is aware, igneous rocks have not been previously reported in the main range, though they are present in Kamas Valley, which separates the western end of the mountains from the Wasatch Range. However, the writer and F. L. Hess found numerous dikes in the quartzite formation in Red Creek and Jessie Ewing Creek (Red Creek quartzite of Powell), and they are reported as present in this formation at other localities. Most of them are dark-green dioritic rocks that have been considerably altered, but a few small peg-

[1] Weeks, F. B., Stratigraphy and structure of the Uinta Range: Geol. Soc. America Bull., vol. 18, pp. 427–448, 1907.

[2] Powell, J. W., Geology of the eastern portion of the Uinta Mountains and a region of country adjacent thereto, p. 137, U. S. Geol. and Geog. Survey Terr., 2d div., 1876.

matite dikes in Jessie Ewing Canyon are composed essentially of quartz, pink feldspar, and muscovite.

STRUCTURE.

The larger structural features of the Uinta Mountains are comparatively simple and are well understood. The detailed structure is in places more complex and for the most part remains to be worked out.

In general, the range is a great east-west anticlinal fold. On the east it gradually merges into the plateau structure of western Colorado, and on the west it narrows and disappears beneath the lavas of Kamas Valley, which separates the Uinta and Wasatch ranges. Formations from pre-Cambrian to Cretaceous were involved in the uplift. Since the uplift erosion has removed many thousands of feet from the summit of the range. At present the central portion is composed principally of the "Uinta" quartzite, surrounded by outcrops of progressively younger formations, through the Cretaceous. Where Green River cuts through the eastern end of the range a small area of pre-Cambrian schists is exposed. The uplift of the range, according to Powell,[1] began at the close of Cretaceous time but continued through early Tertiary, the material removed from the higher portion being deposited around the base.

The fold is unsymmetrical. the crest being considerably north of the center. The south limb is long and gentle, and the north limb is much shorter and steeper and is broken in many places by extensive east-west faulting.

HISTORY AND PRODUCTION.

EARLY RECORDS.

That there has been some mineralization in the Uinta Range has long been known. In 1876 Powell[2] published a map of the eastern portion on which he outlined on the north side of Browns Park a "copper and silver area" coextensive with his Red Creek quartzite, and in 1877 S. F. Emmons[3] noted the occurrence of copper-silver ores on Willow Creek. In 1879 iron ores were shipped from the southwestern part of the range to Park City to be used as flux.[4]

Metals produced in the Carbonate district, 1891–1917.

Year.	Quantity of ore (short tons).	Gold.		Silver.		Copper.		Lead.		Total gross value.
		Fine ounces.	Value.	Fine ounces.	Value.	Pounds.	Value.	Pounds.	Value.	
1891	18	5.22	$108	468	$463	17,784	$2,294			$2,865
1892	73	21.19	438	1,898	1,651	71,136	8,252			10,341
1893	93	26.99	558	2,418	1,886	90,896	9,817			12,261
1894	73	21.19	438	1,898	1,196	71,136	6,758			8,392
1895	36	10.45	216	936	608	35,568	3,806			4,630
1896	111	32.22	666	2,886	1,962	108,680	11,737			14,365
1897	30	8.71	180	780	468	30,900	3,708			4,356
1898	500	96.75	2,000	10,000	5,900	300,000	37,200			45,100
1899	906	175.31	3,624	18,120	10,872	558,800	95,555			110,051
1900	1,751	350.00	7,235	35,020	21,712	1,156,100	191,912			220,859
1901	270	39.18	810	20,250	12,150	108,000	18,036			30,996
1904[a]	500	125.00	2,584	8,000	4,580	25,000	3,125			10,289
1915	6			27	14	5,724	1,002			1,016
1916	5			26	17	5,423	1,334			1,351
1917	5			20	17	4,098	1,119	1,328	$114	1,250
	4,377	912.21	18,857	102,747	63,496	2,589,245	395,655	1,328	114	478,122

[a] The output reported by one company for 1904 was received too late that year for tabulation and the total is not included elsewhere.

CARBONATE DISTRICT.

The largest metal production has been from the Carbonate district, principally from the Dyer copper mine. The history of this district, prepared by V. C. Heikes, follows:

The Carbonate district is in Uinta County, 82 miles north-northwest of Dragon, on the

[1] Powell, J. W., op. cit., p. 201.

[2] Powell, J. W., op. cit., atlas.

[3] Hague, Arnold, and Emmons, S. F., Descriptive geology: U. S. Geol. Expl. 40th Par. Final Rept., pt. 2, p. 270, 1877.

[4] Boutwell, J. M., Iron ores in the Uinta Mountains, Utah: U. S. Geol. Survey Bull. 225, p. 236, 1904.

Uintah Railway, which operates from Mack, Colo., a station on the Denver & Rio Grande Railroad. In 1887 L. P. Dyer and others located the Ace, Antietam, and other claims, some of which were patented and known as the Dyer group. Previous to 1897 old records[1] show the shipment of about 400 tons of copper glance, which assayed an average of 49.47 per cent of copper and 26 ounces of silver and \$6 in gold per ton. During 1897 the only carload shipped contained 51.5 per cent of copper. In the next two years about 200 tons of similar ore was shipped. A 42-inch water-jacket blast furnace was installed in October, 1899, and ran during open seasons for nearly two years. The ore smelted averaged about 33.5 per cent of copper, and in one operation it was possible to produce copper from 95 to 98 per cent pure, as the ore contained no detrimental minerals. The ore and bullion shipped was loaded at Price, Utah, and Carter, Wyo. Since October, 1901, the plant has been idle. The metal production of the district is largely estimated from such records as were available.

ORE DEPOSITS.

IRON ORES.

RHODES PLATEAU.

Iron ores have been developed to some extent at several localities in the range. Among these earliest discovered were the deposits of Rhodes Plateau, which have been briefly described by Boutwell.[2]

LOCATION.

These iron deposits are situated in Wasatch County, Utah, in the southwestern portion of the Uinta Range about 10 miles south of its main divide, on the main divide between Provo and Duchesne drainages at the head of Soapstone Basin, at an elevation of between 9,600 and 9,700 feet above sea level. The locality is easily accessible from the west by way of Provo River and Soapstone Creek. It is reported that the continuation of the same route leading by other deposits to the south may also be taken from the Duchesne on the east.

HISTORY AND DEVELOPMENT.

The iron was probably discovered and first used by the Indians, and a reliable authority informs the writer that the red ore of these iron deposits was used by them for paint.

[1] Pope, R. M., letter to V. C. Heikes, dated Duchesne, Utah, June 5, 1913.

[2] Boutwell, J. M., Iron ores in the Uinta Mountains, Utah: U. S. Geol. Survey Bull. 225, pp. 226-228, 1904.

About 25 years ago the most promising deposits were located by a party from Heber led by a man named Cummings. It is believed that they did the first actual development work on the property and hauled a few loads of ore to the smelters in Salt Lake Valley. Two years later, when Mr. [T. W.] Potts first visited the locality, he noted "two small cuts about 200 feet apart" which "looked as though 10 or 12 tons of ore might have been taken out."[3] In 1879, upon the completion of a smelter at Park City, he mined 200 tons of this iron ore and delivered it at the smelter for flux. The following year he delivered 300 tons, and further shipments were then stopped by the closing of the smelter. It is thus known that shipments were made amounting to 500 tons. It is believed that the total is a little higher. In 1882 or 1883 the ground was surveyed for patent, and seven claims, each 600 by 1,500 feet, were eventually patented to E. P. Ferry.

CHARACTER OF ORE.

The ore is a red hematite of two varieties, the red ocherous and the gray massive semispecular. It varies in purity from samples of higher grade, which are solid pure iron, to samples which are breccias made up of angular fragments of ore, to others which include barren siliceous gangue, and finally to those in which the barren country rock predominating incloses patches of lean ore. The following analysis is of a selected sample of the high-grade, massive, semispecular variety:

Analysis of red iron ore (hematite).

[Analyst, E. T. Allen.]

Fe_2O_3	79.34
Al_2O_3	.15
TiO_2	None.
CaO	None.
MgO	Trace.
SiO_2	18.55
S	None.
P_2O_5	Trace.
Au	None.

The above analysis reveals not only a high content of iron and a suitable amount of silica but also a most desirable absence of the deleterious elements, titanium and sulphur, and only a trace of phosphorus. In short, it indicates a high-grade workable iron ore.

OCCURRENCE OF ORE.

The features shown by the few comparatively restricted croppings, together with those revealed in the two small open cuts, did not afford complete evidence as to the true nature of the occurrence of the iron. The country rock is a gray limestone. In the saddle in which the ore has been worked the general southerly dip of the strata (S. 50° W. 10°) passes into a gentle northerly dip, thus forming a shallow trough. Further, certain disagreements of dips and zones of breccia suggest that the deformation at this point includes not only local folding but also fracturing

[3] The principal historical facts here given are based on information supplied by W. V. Rice, of Salt Lake City, who visited this locality in the early eighties, while associated with the owners of the property from which ore was shipped, and by T. W. Potts, of Woodland, who assisted in the survey of that ground for patent and took the contract to transport the ore to Park City.

sists of 50 to 75 feet of coarse conglomerate overlain by red ferruginous shales and these again by red quartzite. The lower members vary considerably from place to place, the conglomerate member being much thinner in Red Creek Canyon, as reported by F. L. Hess.

The older schists and quartzites are cut by dioritic dikes and in Jessie Ewing Canyon by small pegmatitic dikes. These were nowhere seen extending into the overlying red quartzite series, and as they are more metamorphosed than the red quartzite they are thought to be pre-Cambrian in age.

Faults and fissures connected with the ore deposits in Jessie Ewing Canyon strike in general northeast about parallel to the schistosity of the rocks. Part of the faulting is later than the deposition of the red quartzite, but it is probable that the fissuring connected with the ore deposits is earlier.

ORES.

Many of the fissures are occupied by the dioritic dikes. The ore deposits are very commonly irregular veins of quartz or quartz and carbonate carrying the metallic minerals. Quartz is apparently the prevailing gangue mineral, though a brown carbonate was noted at several places. The original sulphides were pyrite and some copper sulphide, presumably chalcopyrite, and were contained in the veins and disseminated for short distances in the quartzite, schist, and diorite forming the walls.

The copper sulphides at present developed are mainly bornite and chalcocite. The pyrite grains have been fissured and exhibit the structure that Graton has characterized as "exploded bomb structure." In some specimens bornite has replaced almost the whole of the grains, leaving only small cores of pyrite; but in others the bornite forms only as small veinlets in the grains. The bornite in turn has been partly replaced by chalcocite. Commonly the replacement by chalcocite began along the contact of the pyrite and bornite and progressed inward toward the center of the veinlets. In some veinlets the relations indicate that the chalcocite first replaced pyrite and was in turn replaced by bornite, but the relations as a whole strongly indicate the other order. In the field it was considered that the richer sulphide ores had resulted from enrichment by downward-moving solutions. Near the surface much of the copper sulphide has been oxidized to carbonate.

In Red Creek one vein in particular contains considerable hematite. Willow Creek was not visited, but the deposits are said to be similar to those in Jessie Ewing and Red Creek canyons.

URANIUM DEPOSITS.

In some of the deposits in Red Creek Canyon, in the Browns Park area, a small amount of carnotite is found. Its mode of occurrence, according to F. L. Hess, seems to be similar to that of the copper minerals.[1]

OURAY REGION.

DEVELOPMENT.

In the vicinity of Ouray, Uinta County, near the junction of Green and Duchesne rivers, the numerous occurrences of copper ore have been somewhat prospected.

There has been no important production from the region. Early in 1910 a leaching plant was completed by the Uteland Mining Co. on Green River about 5 miles below Ouray but has not been operated.

GEOLOGY.

The consolidated rocks of the region are all Tertiary sediments, and are believed by E. G. Woodruff[1] to belong to the Eocene Bridger formation. They consist of interbedded sandstones and shales—at some horizons of rather thick sandstone beds overlain by thick shale beds, and at other horizons of alternate rather thin beds of sandstone and shale.

The sandstone beds and to a lesser extent the shale beds thin and thicken rather abruptly along the strike; and some of the thinner beds pinch out entirely in a very short distance. Most of the sandstone beds are of medium grain, though some are of coarse sandstone or fine conglomerate. Pronounced cross-bedding is common in the sandstone. The shales are commonly fine clay shales that readily break down on exposure to the weather.

A rock that was noted at several localities in small lenses consists of a fine sandy matrix inclosing small lenticular masses of hardened clay and rather abundant fragmental plant remains.

[1] Oral communication.

At numerous localities the sandy beds contain plant remains, consisting of isolated stems of plants, some of which are several inches in diameter and several feet in length, of abundant leaves, reeds, and fragments collected in lenticular bodies, few of which are more than a few inches to a foot in thickness and more than a few yards in extent.

The sedimentary rocks are nearly horizontal and there is little faulting. Fissuring is most conspicuous where the fissures have been filled with gilsonite. A very few fissures were noted in connection with the copper deposits.

ORES.

The principal prospects thus far developed are 4 to 5 miles north and 3 to 4 miles northwest of the Uteland mill. Other prospects are close to the mill and still others are reported near Green River, a short distance above Ouray.

The typical occurrence of the copper ore is in the sandstone in close association with plant remains that have been in part silicified and in part carbonized. The carbonized portions have been partly replaced by some copper minerals. Chalcocite was the only copper sulphide recognized, but the rather abundant oxide of iron associated with some of the copper carbonate suggests that the original copper mineral may have been in part at least chalcopyrite or bornite.

The ores at the surface are practically all oxidized, prevailingly to malachite. Many fragments of fossil plants in the oxidized material are surrounded by a shell of sand grains cemented by hydrous oxide of iron, outside of which the grains are cemented by carbonate of copper. It seems probable that both the iron and copper have been derived from the minerals that originally replaced the fossil plants, and that during the process of oxidation the copper moved farther outward than the iron.

The replacement of large fragments of plants has produced small bodies of rather high grade ore, and the replacement of small fragments scattered through the sandstone has produced low-grade ore.

The ore bodies outcrop as narrow bands along a cliff or, where the surface chances to be eroded just down to the copper-bearing strata, strew the surface with copper ore over considerable areas. These copper-bearing beds correspond to the lenses containing abundant plant remains and are usually thin, so that in actual mining operations it would be necessary to break considerable waste rock and it would be difficult to prevent its admixture with the ore.

In 1917 it was reported that molybdenum ores had been discovered 2 miles west of Ouray, on the south side of Duchesne River. According to W. T. Schaller the molybdenum is in the mineral ilsemannite, a hydrous sulphate, $MoO_2SO_3.5H_2O$.[1] So far as known there has been no production from this occurrence.

LITTLE SPLIT MOUNTAIN.[2]

Little Split Mountain is in the eastern part of Uinta County, near the point where Green River crosses the Utah-Colorado line.

Copper was discovered in the region about 1896, and it is reported that in 1899 about 5 tons of concentrate, produced by hand-cobbing ore, was shipped to Park City and yielded about 56 per cent copper and 69 ounces of silver per ton. No gold was reported. In recent years there has been no production.

The copper deposits are reached from Jensen, a distance of about 30 miles, by a wagon road that in 1913 was in poor repair.

The rocks of the mountain consist of interbedded sandstones, shales, and limestone with seams of coal of upper Carboniferous age. The rocks have been faulted and dip at angles of 45° and upward.

Copper carbonate and chalcocite occur in a sandstone about 8 feet thick above two seams of coal 6 to 8 inches thick and 10 to 12 feet apart. Above the copper-bearing sandstone is a whiter bed 2 feet thick, which seems to contain no copper. The copper minerals replace plant remains and bones. A little copper occurs in carbonaceous shale below the sandstone.

Gold is reported from the base of the copper-bearing sandstone.

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[1] Schaller, W. T., Ilsemannite, hydrous sulphate of molybdenum: Washington Acad. Sci. Jour., vol. 7, pp. 417-420, 1917.

[2] Based on observations by F. L. Hess.

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SAN RAFAEL SWELL.

By B. S. Butler.

The following summary of the topography and geology of the San Rafael Swell is quoted from Lupton:[1]

TOPOGRAPHY.

The most prominent feature of the topography of this region is a series of buttes, mesas, and "castles," which encircle an area, locally known as "Sinbad," which is 40 to 50 miles long and 10 to 20 miles in width. These fantastically eroded forms represent the outcrop of a gray massive cross-bedded Jurassic sandstone 800 feet thick. It is practicable to cross the Swell at only a few places on account of the almost impassable barrier formed by the sandstone rim. Nearly vertical scarps and canyon walls 300 to 500 feet in height are not unusual. The buttes and "castles" above referred to are conspicuously shown on the San Rafael topographic sheet. Low "hogbacks," formed by resistant beds in the overlying strata, the tops of which produce dip slopes of varying extent depending on the inclination of the beds, encircle this belt of rugged topography. A view to the west from the interior of the Swell gives one the impression of looking up a very gently inclined varicolored stairway, the steps of which increase in height as the top, represented by the Wasatch Plateau, is approached. Badland topography is common, especially near stream courses.

[1] Lupton, C. T., Notes on the geology of the San Rafael Swell, Utah: Washington Acad. Sci. Jour., vol. 2, pp. 185-188, 1912. See also Emery, W. B., The Green River Desert section, Utah: Am. Jour. Sci., 4th ser., vol. 46, pp. 551-577, 1918.

GEOLOGY.

Structurally the Swell is an elongated almost flat-topped dome extending northeast and southwest. The dip of the strata along the west flank is generally less than 10°, whereas that along the east flank is as much as 70°. The strata in the interior of the dome are comparatively flat lying, the principal line of flexure being near the east flank. Local minor domes were noted along the west side. Faults with displacements ranging up to more than 100 feet were observed in and near Cedar Mountain or Red Plateau at the north end of the region. Considerable faulting probably has occurred along the east flank.

Carboniferous (?). Triassic, Jurassic, and Cretaceous formations are well exposed. The lower part of the section described below was correlated with the section noted by Gilbert in the Henry Mountains region, whereas the upper part is almost equivalent to the Book Cliffs section to the north. The lowest rocks exposed in this region are represented by a limestone probably of Carboniferous age noted by F. L. Hess near the San Rafael River on the east side of the Swell. Above the limestone there is a series of several hundred feet of sandstone and shale interbedded which probably are representatives of the Shinarump group (of Permian and Triassic age) and the Vermilion Cliff sandstone (of Triassic age). Unconformably (?) overlying these beds is a massive much cross-bedded gray sandstone 800 or more feet thick. This is the Gray Cliff sandstone (of Jurassic age) of Gilbert's Henry Mountains section, which forms the striking topography referred to above and is in all probability the same as the White Cliff sandstone of the eastern Uinta and southern Utah sections of Powell. Conformably overlying this sandstone is a sequence of 1,350 feet of reddish and gray sandstone, sandy shale, and thick beds of gypsum, which is approximately equivalent to the Flaming Gorge formation of Powell and corresponds closely with the Flaming Gorge formation as described by Gilbert in the Henry Mountains. Five hundred feet of conglomerate, sandstone, and sandy shale of greenish drab color overlying these strata correspond to the larger part of the Henry Fork formation as identified by Gilbert in the Henry Mountains, but probably should be classified with the Flaming Gorge formation of Powell. Sixty to one hundred feet of grayish sandstone (which, near Cedar Mountain, is replaced by conglomerate) and sandy shale with thin streaks of coal at the top and base unconformably (?) overlie the conglomeratic strata just described and probably represent the Dakota sandstone. This sandstone corresponds to the uppermost part of Gilbert's Henrys Fork formation. The Mancos shale, about 4,000 feet thick and consisting of three members, rests upon the Dakota (?) in apparent conformity. In places, however, a thin bed of conglomerate separates the Dakota(?) sandstone from the overlying shale. The Mancos outcrops in a monoclinal valley, the west part of which is known as Castle Valley. The lowest member consists of about 600 feet of bluish-drab shale which is sandy in its lower and upper portions. Overlying this is a sandstone member approximately 500 feet thick containing coal beds near the top. This sandstone probably is equivalent to the Bluegate sandstone of Gilbert's Henry Mountains section and is represented at the north end of the Swell in the vicinity of Sunnyside Junction by a thin concretionary sandy formation. Overlying the sandstone is about 3,000 feet of grayish-drab shale, which is sandy in its lower and upper parts. Conformably overlying the Mancos shale is the Mesaverde formation, 1,100 feet thick (in the vicinity of Emery), which caps the east scarp of

the Wasatch Plateau. This formation consists mainly of sandstone with beds of sandy shale and coal intercalated.

Sills and dikes of basalt, which were noted at several localities near the south end of the Swell, extend as far north as Muddy or Curtis Creek.

ORE DEPOSITS.

No mining was carried on in the vicinity of the San Rafael Swell until the discovery of the rare metals a few years ago led to prospecting and to the shipment of considerable ore.

URANIUM-VANADIUM-RADIUM DEPOSITS.[1]

Uranium and vanadium deposits have been found at numerous points along the San Rafael Swell; and ores have been mined and shipped principally from the claims of the Radium Co. of America, about 12 miles west of Green River and a little north of the point where San Rafael River passes through the reef and from the deposits at Temple Rock, toward the southern end of the reef, about 45 miles from Green River.

The uranium-vanadium deposits along the San Rafael Reef occur at two horizons, though at neither are they confined to a single definite bed[2] but occur in sandstone strata separated in places by beds of shale.

The lower horizon is in the Triassic shales below the reef sandstone at or near the horizon of the Shinarump conglomerate. The principal mining at this horizon has been at Temple Rock, though prospects have been located to both the north and the south and deposits are reported from the west side of the Swell. At Temple Rock the uranium and vanadium minerals occur in strata of sandstone and are usually associated with fossil plant remains.

The upper horizon is in the McElmo formation. As at other localities in the State the minerals impregnate the sandstone and replace the plant remains in certain strata of sandstone. The deposits usually form lenses of no great extent and in places replace only a single tree trunk.[3]

Mining on the claims of the Radium Co. of America began in 1912 and has been conducted intermittently since that time. Deposits in the sandstone of the McElmo are reported farther north on the Swell.

[1] See also Hess, F. L., Carnotite near Green River, Utah: U. S. Geol. Survey Bull. 530, pp. 161-164, 1913.

[2] Boutwell, J. M., Vanadium and uranium in southeastern Utah: U. S. Geol. Survey Bull. 260, p. 200, 1905.

[3] Howard, L. O., The development of our radium-bearing ores: Salt Lake Min. Rev., Feb. 28, 1914.

COPPER DEPOSITS.

Copper deposits in the sandstone have been reported at several places along the east side of the Swell but have not been visited by the writer. They are reported to be similar in character to the "red bed" deposits in other parts of the State.

LA SAL MOUNTAINS.

By B. S. Butler.

GENERAL FEATURES.

The La Sal Mountains are in eastern Utah, a few miles from the Utah-Colorado State line in Grand and San Juan counties—about half in each. The region is reached from the Denver & Rio Grande Railroad from either Thompson or Cisco. From Thompson a daily stage runs south for about 35 miles to Moab, which is the distributing center for the western and southern side of the range. From Cisco a stage line runs 38 miles to Richardson and Castleton, at the base of the north end of the range.

The La Sal Mountains are an irregular group about 15 miles long from north to south and 4 to 6 miles wide. The highest peak, Mount Peale, is slightly over 13,000 feet high, and several peaks reach 12,000 feet. The higher peaks rise 5,000 to 6,000 feet above the surrounding plateau.

Surrounding the central mountain mass is a plateau or mesa that in many places has not been maturely dissected by the streams and that forms benches sloping gently from the mountains. The drainage is radial from the central mass and is typical of the laccolithic mountains of the plateau country. The drainage from the west side is to Grand River and from the east side to the Dolores and thence to the Grand. A short distance from the mountains the streams are in canyons, but near the mountains an old mature erosion surface is still preserved, and it is possible to irrigate the mesas surrounding the mountains from the streams before they enter the canyons.

Water is scarce throughout the area. Small streams, some of which persist throughout the summer, flow from the mountains, where snow lies till late in the spring. The stream in Spanish Valley is the largest and irrigates several hundred acres about Moab. Other streams serve to irrigate a few ranches. On the high mesas small areas are irrigated and dry farming is conducted with considerable

success. The agricultural possibilities of the region seem sufficient to supply any mining community that is likely to develop. On the higher slopes of the mountains is considerable timber that is suitable for building and for mine timbering.

GEOLOGY.

The prevailing rocks are sedimentary, the igneous rocks being confined to the core of the mountains.

SEDIMENTARY ROCKS.

SEQUENCE AND CORRELATION.

The following generalized section shows the sequence of the rocks and their correlation with those to the west:

Approximate correlation of formations in southwestern Colorado and eastern Utah.

San Juan Mountains, Colo. (Cross).	La Sal region, Utah.		Uinta Mountains, Utah (Powell).
		Feet.	
Mancos.	Mancos shale.	3,000	Henrys Fork.
Dakota.	Dakota sandstone.	40+	
	—Unconformity—		
McElmo.	McElmo formation (sandstone and shale).	1,200	Flaming Gorge.
La Plata.	La Plata sandstone (gray sandstone).	650-800	White Cliff.
	Unconformity—		
Dolores.	Triassic (sandstone with shale at base).	300-350	Vermilion Cliff.
	—Unconformity—		
Cutler. Rico.	Permian (sandstone and shale, gypsiferous).	50-800?	Shinarump.
Hermosa.	Pennsylvanian (limestone and sandstone).	1,000?	Aubrey.

CARBONIFEROUS SYSTEM.

The oldest sedimentary rocks recognized in the region are interbedded limestone, sandstone, and shale of Pennsylvanian (upper Carboniferous) age.[1] Newberry describes over 1,200 feet of Carboniferous sediments from Canyon Colorado, a few miles above the junction of Grand River. Powell collected Carboniferous fossils from the rocks at the junction of Grand and Green rivers. Cross describes a section about three-fourths of a mile northwest of Grand River, on the stage road between Moab and Thompson, which consists of 539 feet of interbedded limestone, sandstone, and shale underlying a cliff of red, pink, and gray sandstone, apparently embracing the Vermilion Cliff sandstone and possibly a part of the White Cliff sandstone. "The upper 104½ feet of the section represents the fossiliferous Triassic beds immediately below the Vermilion Cliff sandstone. * * * The next 44 feet of beds is provisionally referred to the Permian." The remainder of the section is believed to be Pennsylvanian. Pennsylvanian strata were observed by the Cross party in Sinbad Valley, Colo., and had been previously reported from that locality.

Southeast of the La Sal Mountains, in Big Indian Valley, an anticline striking northwest has brought up the Carboniferous rocks. About 10 miles southeast of La Sal the northeast wall of the valley for several miles is formed of interbedded sandstones and limestones. Fossils collected from these were determined by G. H. Girty as follows:

Lot A.

Fistulipora sp.
Batostomella sp.
Streblotrypa? sp.
Chonetes aff. C. granulifer.
Productus pertenuis.
Marginifera wabashensis.
Rhynchopora aff. R. nikitini.
Rhynchopora aff. R. illinoisensis.
Squamularia perplexa.
Spiriferina kentuckyensis.
Bellerophon sp.

Lot B.

Echinocrinus sp.
Batostomella sp.
Productus semireticulatus.
Productus cora.
Productus nebraskensis?
Productus pertenuis?
Marginifera wabashensis.
Rhynchopora aff. R. nikitini.
Rhynchopora aff. R. illinoisensis.
Squamularia perplexa.

Of these Mr. Girty says: "Lots A and B are closely related and are clearly of Pennsylvanian age. I would hardly regard them as late Pennsylvanian, and certainly they are not Permian." Stratigraphically the limestone

[1] Cross, Whitman, Stratigraphic results of a reconnaissance in western Colorado and eastern Utah: Jour. Geology, vol. 15, pp. 634-679, 1907.

series appears to be the equivalent of that described by Cross near Moab.

The members immediately above the Pennsylvanian limestone underlie Big Indian Valley at the point where they were crossed and therefore could not be examined; but, as Big Indian Valley is a strike valley, it may be inferred that they are weak rocks, probably comprising much shale. The southeast wall of the valley consists of a thick series of red sandstones which are apparently equivalent to the Dolores formation to the east and the Vermilion Cliff to the west.

Several hundred feet of sandstone and shales and gypsiferous beds, reported to lie between the Pennsylvanian limestone series and the Triassic at several localities in the vicinity of the La Sal Mountains, is regarded as of Permian age. Cross has described such beds from near Moab, and gypsiferous beds believed to overlie the Pennsylvanian limestone in the lower part of Spanish Valley probably belong to the same series. Gypsiferous beds were observed by the Cross party in Fisher Valley, north of the La Sal Mountains.

Cross also describes a sub-Triassic formation on West Creek near the Utah-Colorado line as having a thickness of 870 feet of conglomerate arkose and shale. What seems to be the same formation is reported by Peale from southeast of the mountains, and there seems little doubt that it occurs throughout the region. There is believed to be a pronounced erosional unconformity at the base of the Triassic, and it is possible that at some places the underlying beds were completely eroded. This formation is believed to be the equivalent of the Cutler and Rico formations of the San Juan region and a part of the Shinarump group of Powell.

TRIASSIC SYSTEM.

The strata between the unconformity at the top of the Permian and the base of the massive gray sandstone above are considered to be Triassic. As measured by the Cross party near Moab they form a massive cliff of red sandstone about 200 feet thick overlying 100 feet of more shaly beds. The total thickness of the strata is probably 300 to 350 feet. They entirely surround the range and are usually conspicuous. They are equivalent to the Dolores of the San Juan region and to the Vermilion Cliff and the upper part of the Shinarump group of Powell.

JURASSIC SYSTEM.

The Jurassic is represented by the La Plata and McElmo formations. The La Plata, in the vicinity of Green River, is described by Lupton [1] as a cross-bedded coarse-grained very massive gray sandstone about 700 to 800 feet thick.

South of the La Sal Mountains, as described by Cross, it consists of three members—a lower gray massive cross-bedded sandstone 250 feet thick; a middle member of about 100 feet of thin-bedded strata, sandstone for the most part, with shaly and impure calcareous members between, and an upper member of fine and even-grained, strongly cross-bedded, yellowish or pinkish, massive sandstone about 300 feet thick. The total thickness of the La Plata south of the La Sal Mountains is therefore about 650 feet. The formation thins eastward till in its type locality in the Telluride quadrangle it is only about 100 feet thick. The La Plata is considered by Cross to rest unconformably on the Triassic, but in the La Sal region the unconformity is not conspicuous.

The McElmo formation, in the vicinity of Green River, is divided by Lupton [2] into three members. A lower red sandstone, thin bedded above and massive below, 700 feet thick; a middle member, the Salt Wash sandstone ("gray conglomeratic sandstone which outcrops in cliffs. The sandstone in places is lenticular, soft, and friable"), thickness 150 to 175 feet; and an upper member of "gray conglomerate, variegated sandy shale and clay, and a few feet of limestone about 175 feet from the top," thickness, 325 to 350 feet, making a total thickness for the McElmo formation of about 1,225 feet. This formation, which has been generally regarded as the equivalent of the Flaming Gorge of Powell, outcrops at many points around the La Sal Mountains and undoubtedly once covered the region.

CRETACEOUS SYSTEM.

The Cretaceous in the vicinity consists of the Dakota sandstone, which lies unconformably on the Jurassic rocks, and of the Mancos shale. The thickness of the Dakota sandstone is variable. In the vicinity of Green River Lupton gives it as about 40 feet, but south of the range it is said to be considerably greater.

[1] Lupton, C. T., Oil and gas near Green River, Grand County, Utah: U. S. Geol. Survey Bull. 541, p. 125, 1914.
[2] Op. cit., p. 11.

Overlying the Dakota sandstone is the Mancos shale, which, according to Lupton, consists of about 3,000 feet of shale with interbedded sandstone. Only the basal portion is exposed near the La Sal Mountains.

TERTIARY AND QUATERNARY SYSTEMS.

Tertiary rocks are not known near the mountains. Quaternary deposits comprise the glacial deposits in the higher parts of the range, usually not extending below 10,000 feet, and the gravel deposits in Wilson Mesa.

IGNEOUS ROCKS.

The following description of the igneous rocks is abstracted from Hill's report:[1]

The core of the La Sal Mountains is composed of a series of rocks probably all of which are derived from the same magma. The earliest and by far the most widely distributed rock is a light-gray, fine to medium grained porphyry, with distinct phenocrysts of plagioclase and hornblende and smaller ones of pale-green augite. Normally this rock shows no quartz, but here and there blebs are noted up to one-eighth inch in diameter. Orthoclase phenocrysts are seen in some specimens, but this mineral is usually more abundant in the groundmass, a large proportion of which is made up of finely granular plagioclase. The normal rock is a monzonite porphyry, but with more abundant quartz it approaches quartz monzonite porphyry. The monzonite porphyry forms the main intrusive mass and also the knob northwest of Castleton.

At least two and possibly three sets of dikes cut the monzonite porphyry in a general north-northeast direction. They range from a few feet to 100 feet in width but are relatively short. The most common type has a fine-grained gray feldspathic groundmass containing conspicuous tabular phenocrysts of plagioclase and orthoclase up to half an inch or more in diameter and a small proportion of ferromagnesian minerals. This rock has been classed by Prindle[2] as syenite porphyry. It weathers gray to yellow and is, as a rule, not iron stained except near veins.

A second type of porphyry dike rock, called by Prindle noselite syenite porphyry, occurs in a few dikes 20 feet or less in thickness in the monzonite porphyry and the syenite porphyry. It is composed of very large zonally banded orthoclase crystals up to 1½ inches across set in a medium-grained porphyritic groundmass. The groundmass, which constitutes less than one-third of the rock, contains megascopic crystals of orthoclase, pyroxene, and noselite in a feltlike mass of orthoclase (without crystal outlines) and aegirite needles. The orthoclase crystals are rounded and in places weather out of the groundmass as nearly perfect crystals. The groundmass becomes pitted and brownish-yellow on weathering.

A third type of dike rock, quartz monzonite porphyry, was found only about half a mile west of Basin post office, and there the croppings were largely covered by slide rock. The material is all intensely altered, leaving a yellowish-white pitted groundmass showing scattered plagioclase feldspars with abundant quartz blebs and prismatic crystals of altered white orthoclase from one-eighth to three-fourths of an inch in longest dimension. It may be that this is simply a very siliceous phase of the monzonite porphyry, though its high orthoclase content makes it appear to be a distinct type.

The sedimentary beds adjacent to the intrusive rocks seem to contain no contact-metamorphic minerals, and the descriptions of these mountains make no mention of contact metamorphism. Cross says:

> One interesting difference between these magmas [the laccolithic] and the closely allied ones of the Elk Mountain diorites has already been alluded to. Not only are the sediments adjoining the laccolithic masses unattacked by heat, but they seldom exhibit any development of secondary minerals as contact phenomena.

The age of the laccolith can not be fixed definitely. The Mancos shale is involved in the doming, so the intrusion is later than Early Cretaceous. Cross places it as Tertiary, on an estimate of the time required for the erosion of several thousand feet of sediments that hypothetically must have overlain those now exposed at the time of the intrusion to account for the uniform conditions of cooling shown by the porphyries of the several laccolithic groups through a great vertical range.

Analyses and descriptions of the principal rocks, types of the La Sal Mountains, are given on page 93.

[1] Hill, J. M., Notes on the northern La Sal Mountains, Grand County, Utah: U. S. Geol. Survey Bull. 530, pp. 100-108, 1913.

[2] Prindle, L. M., Analyses of rocks and minerals: U. S. Geol. Survey Bull. 419, pp. 120-121, 1910.

STRUCTURE.

DOMES.

The La Sal is a typical laccolithic mountain group (p. 93), being formed by igneous rocks that have risen through relatively narrow fissures and spread out between certain strata doming the overlying rocks. From every direction the higher surrounding strata tend to curve upward. The rocks at the base of the mountains, however, in many places show little disturbance till very close to the igneous core and in some localities they do not curve up at all but are crosscut by the igneous intrusion. For the most part the intrusion appears to dome the Cretaceous shales and to crosscut the Jurassic and Triassic sandstones.

FOLDS.

Folding is conspicuous and important. A series of broad open major folds extends for 40 miles northwest and southeast, with the La Sal Mountains near the center. At some points these folds resemble domes[1] rather than true folds and some of them may owe their origin to underlying intrusive bodies. A mass of "porphyry" near the axis of the anticline several miles from the central core of the mountains suggests such an origin for Castle Valley. Anticlinal valleys have commonly developed along the crests of the anticlines. Conspicuous among them are Castle Valley and its extension, Salt Wash, northwest of the mountains, and Sinbad, Paradox, Gypsum, and Big Indian valleys southeast of the mountains.

FAULTS AND FISSURES.

Faulting has been far less important in the region than folding, though numerous faults are present and some are of large extent. The faults are less conspicuous than the folds and are not clearly understood. Cross [2] has noted a zone of faulting traversing Spanish Valley, and Peale has described an important fault parallel to Sinbad,[3] Gypsum, and Paradox valleys.[4]

Boutwell [5] has described a zone of deformation trending northeast across Richardson Amphitheater. Minor faults have been noted in the region of Castle Valley by Hill,[6] and detailed work will doubtless disclose many more faults in the region.

Fissures, or breaks in the rocks along which there has been but little movement, are numerous and are associated with the ore deposits in the intrusive rocks and with some of those in the sedimentary rocks.

MINING HISTORY.

The early history of the district is given by Hill [7] as follows:

> The earliest discoveries of minerals in this area were made about 1886, the first location being made in 1888 on the ridge between Bachelor and Miners basins, on what is now the High Ore claim. Practically no mining was done in these mountains until 1896, when a party of prospectors did some work that resulted in the discovery of the Tornado deposit in 1897. * * * Shortly after the discovery of the Tornado, a small stamp mill was installed in Miners Basin. * * * After about 100 tons of ore had been run through the mill it was closed and has not been operated since.
>
> In 1907 it was first noted that the gravels on Wilson Mesa carried gold. For two years these gravels were washed by crude methods, and in 1910 a little excitement was created in Salt Lake and Grand Junction over the richness of the deposits.
>
> There has been practically no production from the quartz mines, and it is probable that $5,000 would cover the entire output from both quartz and placer mining in the region.

The prevailing high price of copper previous to the marked decline in 1907 greatly stimulated prospecting and development in the sedimentary formations around the La Sal Mountains, notably in the Big Indian Valley south of the range and to a less extent in Lisbon Valley southeast of the range, in Salt Wash northwest of the range, and elsewhere. The decline in 1907 retarded development, however, and though a few tons of ore were shipped from the different copper prospects there was no important production, and little development work was done at most of the properties for several years. In 1917 a mill was completed for treating the ores of the Big Indian mine.

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[1] Peale, A. C., U. S. Geol. and Geog. Survey Terr. Ninth Ann Rept., for 1875, pt. 1, p. 63, 1877.

[2] Cross, Whitman, Stratigraphic result of a reconnaissance in western Colorado and eastern Utah: Jour. Geology, vol. 15, pp. 634-679, 1907.

[3] Peale, A. C., op. cit., p. 62.

[4] U. S. Geol. and Geog. Survey Terr. Tenth Ann. Rept., 1876, pt. 1, pl. 9, 1878.

[5] U. S. Geol. Survey Bull. 260, p. 205, 1905.

[6] Hill, J. M., Notes on the northern La Sal Mountains, Grand County, Utah: U. S. Geol. Survey Bull. 530, p. 108, 1913.

[7] Idem., p. 103.

Vanadium and uranium minerals were discovered about 1898 near Richardson [1] by a man named Walsh and were developed to some extent soon after. The first shipment was made in 1904, when more than half a carload was sent to Buffalo, N. Y., for experimental purposes. Since 1898 numerous deposits have been discovered around the La Sal Mountains in Utah and considerable ore has been shipped.

ORE DEPOSITS.

PLACER DEPOSITS.

The placer deposits of Wilson Mesa have been described by Hill [2] as follows:

The flat mesas south of Castle Valley are covered by a coating of gold-bearing gravel. This deposit is usually very thin, being indicated by scattered boulders and pebbles or by small flattened mounds of like material here and there on the sandstone bedrock. In a few places it attains greater thicknesses. Some of the larger deposits stand as low rounded knobs, but most of them seem to occupy reentrants in cliffs. The latter was apparently the position at the Point Lookout placer. A combination of the two forms is seen at the Black Cap workings. A third and much rarer occurrence is along what appears to be an old channel which runs northwestward from the Black Cap.

The gravels are the same throughout, consisting of subangular cobbles of igneous material similar to that seen in the La Sal Mountains to the east, with a relatively small proportion of sandstone fragments. They range in size from one-fourth of an inch to 2½ feet, with an average size of about 10 to 12 inches. Fragments of monzonite porphyry cut by quartz stringers are fairly abundant and magnetite cobbles up to 4 or 5 inches in diameter are not at all rare. There seems to be a slight decrease in size of the bonlders at the western edge of the deposits, but it is not everywhere the same and is rather doubtful. There is practically no stratification of these gravels except along the present drainage lines in reworked material.

The gold, said to be worth from $19 to $20 an ounce, occurs in small wires or flakes, and none of that seen appeared to be much water worn. It is distributed throughout the thickness of the deposits, which are said to be of about the same grade from the surface to bedrock. Besides the gold that can be recovered by washing, it has been found that the "ribbon rock" (the monzonite porphyry cut by quartz stringers) contains a fairly large portion of the gold value of the gravels. Some of the miners assert that for every ounce saved by sluicing 10 ounces is lost in the ribbon rock which goes over the dump.

There is no natural water supply on Wilson Mesa. A ditch originally built for irrigation is said to supply about 12 cubic feet a second from the beginning of the thaw in April to the last of July, when the greater part of the snow has disappeared from the mountains. From then until October the supply is about 8 cubic feet a second, and it is further diminished during the winter. The water is all taken from Mill Creek, and considerable trouble has been experienced in obtaining enough for sluicing, as the town of Moab also takes its supply from this source and has a prior right to the water.

The origin of the gravels has not been definitely proved. They are similar in character to gravels around the Uinta Mountains that Powell and later writers have attributed to stream action when the mountains were higher and the precipitation greater. On the other hand, Atwood has described somewhat similar gravels in the San Juan Mountains, Colo., which he attributes to an early period of glaciation. Hill states that the gravel is composed largely of igneous rocks similar to that in the range and there seems no doubt that it was derived from the higher parts of the range.

Gold-bearing gravels in Miners Basin are described by Hill [3] as follows:

The town of Basin is located on a flat just above a very small, indistinct terminal moraine of the last glacial epoch. This moraine is composed entirely of angular igneous material, none of which has traveled over a mile and much of it a very inconsiderable distance. The moraine lies on the top of a débris-filled V-shaped valley. Both the glacial material and the débris contain a little fine free gold. The amount of material is, however, very small and hard to handle on account of the large angular talus blocks included in it.

GOLD-COPPER VEINS IN INTRUSIVE ROCKS.

The following description of the veins in the monzonite porphyry is also from Hill: [4]

There has been very little work done on the mineral deposits of the La Sal Mountains. The greatest depth reached is perhaps 150 feet below the surface, and 95 per cent of the shafts and tunnels are not more than 50 feet below the grass roots. The general procedure seems to have been to locate a mineralized zone on the hill slope and then go into the valley bottom and start a long crosscut to reach it in depth. As yet few of these crosscuts have reached the desired goal.

The general direction of the lodes seems to be northwest and southeast to east and west, with one or two east-northeast fractures. The northwest-southeast trend corresponds in a general way to the longer axis of the intrusive mass.

There are two rather distinct types of deposits—one characterized by glassy quartz with copper, silver, and gold, and the other with apparently the same kind of quartz, but containing largely gold in a pyritic carrier. The deposits of the former type are usually simple, rela-

[1] Boutwell, J. M., U. S. Geol. Survey Bull. 260, p. 207, 1905.
[2] Hill, J. M., op. cit., p. 114.
[3] Idem, p. 117.
[4] Idem, p. 110.

tively narrow quartz veins that have affected the walls to a much less degree than the second type. The gold-pyrite deposits appear to be stockworks or zones of minute branching, interlacing quartz-filled fissures. In the deposits of this type the wall rock is altered and impregnated with pyrite, forming masses of low-grade ore as much as 20 feet across. These two types, though more or less distinct, merge into each other and in places the gold-pyrite deposits show copper minerals. Veins characterized by carbonate gangue were seen in two places and carry both pyrite and chalcopyrite.

The ores so far developed are largely oxidized, but remnants of chalcopyrite and pyrite are found surrounded and cut by masses of limonite, malachite, and chrysocolla. These three oxides are more or less mixed, the iron being much more abundant than the copper minerals, forming a low-grade copper-pitch ore. Very minor amounts of bornite and chalcocite occur in Beaver Basin, but were not noted elsewhere. Azurite is rather uncommon. Glassy, coarsely crystalline quartz is by far the most abundant gangue mineral. It is usually rather smoky but may be clear. Calcite and siderite are seen in some veins, and associated with them in one place is a very minor amount of fluorite. Barite with limonite was noted in one deposit in sandstone near the monzonite porphyry. The association of glassy quartz with much copper-bearing limonite in small stringers is commonly seen in the brownish float of the mountains.

The lodes are later than all the porphyries except possibly the very siliceous quartz monzonite mass half a mile west of Basin. It seems possible that they may be the final product of the intrusion.

COPPER DEPOSITS IN SEDIMENTARY ROCKS.

DISTRIBUTION.

At several localities around the La Sal Mountains copper and copper-silver ore has been found in sufficient abundance to encourage prospecting; and the Cashon mine, Montrose County, Colo., has produced important amounts of copper and silver. Prospecting has been carried on in Big Indian Valley south of the range, Lisbon Valley southeast of the range, Salt Wash Valley northwest of the range, about 9 miles east of Dewey, and to a slight extent at numerous other localities. At the time of the writer's visit, in 1913, all the copper properties were idle and the following notes are the result of such examination as could be made under the existing conditions.

BIG INDIAN VALLEY.

The deposits in Big Indian Valley are 4 to 5 miles south of La Sal post office and are reached from Thompsons, the nearest railroad point, by way of Moab, a distance of 75 miles by road. The ores occur in gray medium-grained sandstones with lenses of rather fine conglomerate. The beds are believed to be at about the middle of the Triassic (at or near the horizon of the Shinarump conglomerate), beneath the prominent cliff-making (Vermilion Cliff) sandstone. The thickness of the beds in which mineralization has been shown is probably 200 to 300 feet, though it is only at certain horizons through this thickness that the rocks have been mineralized to an important extent.

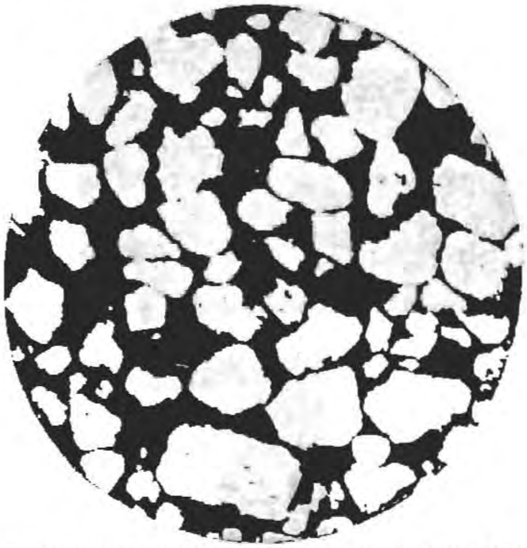
In the mineralized zone there has been considerable fissuring of the sandstone. The most prominent fissures strike about N. 50°–70° W. magnetic; others strike in other directions, notably nearly north. Some movement along the fissures is indicated by slickensiding, but no important displacement was noted. Along most of the fissures there has been mineralization, which on the surface appears as carbonate of copper and hydrous oxides of iron with some manganese oxide.

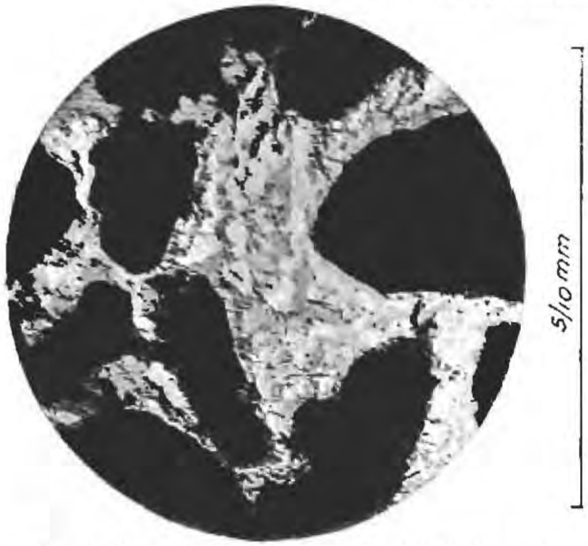
In the vicinity of the fissured area the more permeable sandstones, particularly the conglomerate lenses, have been impregnated by copper minerals, which were deposited between the pebbles. In many places a very close connection between the impregnated sandstone and the fissures is not apparent; but as the mineralized rock is confined to the fissured zone it seems reasonable to suppose that the solutions migrated from the fissures.

Mineralization has taken place along the general strike of the fissuring for 1½ to 2 miles. Approximately a mile northwest of the Big Indian mine a shaft has been sunk to a depth of perhaps 100 feet; some good ore was on the dump, and shallow openings along the ledge show copper carbonates. Mineralized rock can be found for at least half a mile southeast of the Big Indian mine, but not in sufficient quantity to have encouraged extensive prospecting.

At the surface and in the shallow workings the copper minerals are those that have resulted from oxidation processes, mainly azurite and malachite and some cuprite. They are disseminated through the sandstone or occur (the carbonates particularly) as botryoidal masses lining fissures or cavities. On the dump specimens containing sulphides were found, indicating that the oxidized ores were probably derived from sulphides.

Specimens of the impregnated sandstone sulphide ore are seen under the microscope to consist of sand grains cemented by sulphide. Many sand



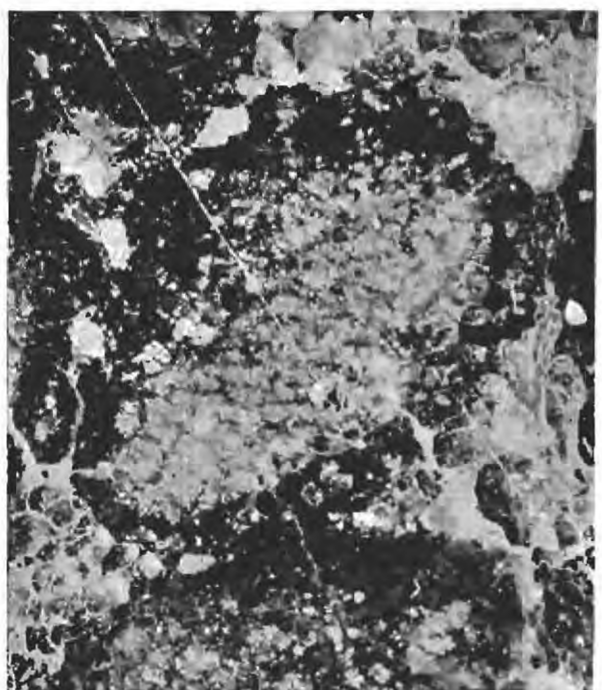


A. PHOTOMICROGRAPH OF SANDSTONE COPPER ORE.

Light areas, quartz grains; dark matrix, copper sulphides (chalcocite and chalcopyrite).

B. PHOTOMICROGRAPH OF SANDSTONE COPPER ORE, SHOWING COPPER SULPHIDE MATRIX.

Black areas, quartz grains. Gray mottled areas, copper sulphide; light areas, chalcopyrite; dark areas, chalcocite.



C. CONCENTRIC BANDS OF PYRITE AND COVELLITE.

Central area, largely pyrite, with veins of covellite. Enlarged 25 diameters.

D. NODULES OF PYRITE SURROUNDED BY COVELLITE.

Light areas, nodules of pyrite; dark borders, covellite; pyrite of central area partly replaced by covellite. Enlarged 25 diameters.

PHOTOMICROGRAPHS OF ORE FROM THE BIG INDIAN MINE, LA SAL MOUNTAINS.

grains are completely surrounded by the sulphide (see Pl. L, *A*) and are separated from other grains by one-fourth to one-third of their diameter. Occasionally the sulphide is in a fissure in the grain. As the grains in the normal sandstone are commonly in contact, it seems that some of those in the ore must have been partly replaced by the sulphide. The sulphide is in large part chalcocite, in which are remnants of a yellow sulphide (see Pl. L, *B*), apparently chalcopyrite. The chalcocite has formed largely, if not entirely, as a replacement of this sulphide.

Nodular masses of sulphide resembling concretions, found on the dump, consist of quartz grains with much more sulphide cementing material than the ordinary sandstone ore. The cement is a yellow sulphide, probably pyrite, and a mottled blue and blue-gray material, which may be a mixture of covellite and chalcocite. From a sixteenth to an eighth of an inch from the surface of the nodules the yellow sulphide is absent, while within this outer zone it may form a large percentage of the material (see Pl. L, *D*). One small nodule was examined which showed concentric zones of the yellow and blue sulphides (see Pl. L, *C*). The natural explanation of the occurrence of the sulphides seems to be that first the yellow iron sulphide was deposited and that later it was in part replaced by the copper sulphides which in turn were for the most part altered to carbonates.

The most extensive development is at the Big Indian mine, which has been prospected by several tunnels and an inclined shaft. Only part of the underground works could be examined. Some good ore has been found, but the richer grade is in small bodies and would be difficult to mine without mixing with poor ore or waste. The great bulk of the mineralized rock carries a rather low percentage of copper, and much of the low-grade ore occurs in thin lenses and is difficult to extract without breaking barren rock.

LISBON VALLEY.

The deposits in Lisbon Valley are near the Colorado-Utah line, 12 to 14 miles southeast of La Sal post office. The ores occur in sandstones with interbedded shales and at least one bed of carbonaceous shale containing much coaly material. The exact stratigraphic horizon was not determined, but it is believed to be near the base of the Triassic.

In the vicinity of the Lisbon mine the beds strike about N. 70° W. (magnetic) and dip about 40° SW. The ore is disseminated in sandstone. Surface trenching has revealed several mineralized horizons, but the main development consists of an inclined shaft which follows a sandstone stratum containing plant remains, which is underlain by carbonaceous shale containing seams of coaly material.

The ore, so far as observed, is all oxidized and occurs as a cement of the sandstone and, to some extent, in the carbonaceous material in the sandstone. It also occurs as botryoidal masses lining openings in the rocks. The coaly material underlying the sandstone is said to carry a low percentage of copper. Material of this character was collected and when examined several weeks later was seen to contain a light-green material that had formed as an efflorescence on the surfaces and along fractures. When treated with water a solution containing copper and iron sulphate is obtained. Probably most of the copper is present as sulphate and has possibly leached downward from the sandstones above.

The coarse strata have apparently been most favorable to the deposition of the metallic minerals. No important fissures connected with the deposits were noted, but careful study would possibly reveal such.

In the inclined shaft, which has been sunk to a depth of perhaps 100 feet, some ore of good grade has been taken out; and in trenching across the formation and by other shallow workings several other mineralized strata have been found. At the time of visit only a small tonnage of ore had been extracted or developed.

SALT WASH.

Salt Wash Valley is cut in the crest of a broad anticline extending from near Thompsons southeast to Grand River and the La Sal Mountains. Its floor slopes northwest and southeast from a divide about halfway between Thompsons and Grand River. The formations along it were not carefully traced into areas where they are known, but it is thought that the copper-bearing beds are in the McElmo formation. The sediments near the copper deposits at the north end of the belt are mainly gray sandstone with some shale and calcareous

beds. The southern end of the belt was not visited but is reported to be at essentially the same stratigraphic horizon. Toward the north, where the prospects were visited, there has been considerable fissuring parallel with the anticline and in some places there has been movement along the fissures, though the displacement has probably not been great.

The copper deposits occur on both sides of the valley, from about 10 miles southeast of Thompsons nearly to Grand River, in the portions of the anticline nearest the crest. No deposits have been reported from the flanks of the anticline. The ore deposits are in the vicinity of fissure zones, but the ores do not generally occur in the fissures, usually impregnating the sandstone. Near the old Indian trail a small stringer of ore apparently occurs in a fissure. A common occurrence of the copper minerals is as small spherical concretions in the sandstone, usually not more than one-half inch in diameter, but in places thickly scattered through certain beds. At the surface these spheres weather out and collect in depressions, where a small amount of rather high grade ore can be scooped up. The prevailing minerals are the carbonates, azurite, and malachite, the blue carbonate usually predominating. Microscopic examination of the spherules revealed the presence of a little gray and yellow sulphide—probably chalcocite and pyrite. Iron and manganese oxides are rather abundantly associated with the copper minerals, and some spheres of iron and manganese oxides similar to those of copper carbonate and some concretions of calcite were noted.

Some of the copper ores, notably those from the fissure near the old Indian trail, are said to contain considerable silver. This ore contains barite as a gangue mineral, and the presence of rather abundant remnants of chalcopyrite indicates that that mineral was the most important original copper sulphide. A greenish-yellow earthy mineral, observed at several localities near the north end of the belt, and associated in small amounts with the copper and iron minerals, was found not to contain vanadium nor uranium, though in general appearance it resembles low-grade carnotite sandstone ore.

Remnants of sulphides in the carbonate ore indicate that the copper and iron were probably originally deposited as sulphides and were later oxidized.

Little ore has been shipped. When copper is high, it would probably be profitable to gather the surface ores, but it is doubtful if systematic exploitation of the deposits would meet with much success.

Hill[1] describes a deposit east of Dewey as follows:

About 9 miles east of Dewey, the halfway station on the Cisco-Castleton road at Grand River, a copper-silver mine entirely in sandstone, with no igneous rock in the vicinity, is said to be producing some ore. The property was not visited, but the writer had an opportunity to see some of the ore. It consisted of chalcocite deposited in small seams cutting white sandstone and also disseminated in the adjacent walls. Along the borders of these seams a thin zone of malachite is usually present, and this mineral, together with azurite, stains the sandstone near the fissure. The mine is now being worked for its silver, which occurs in native form and as silver chloride. The development is rather shallow. The vein is said to strike a few degrees north of west and to be traceable for more than a mile.

Emmons[2] has described an apparently similar deposit on the east side of the La Sal Mountains in Montrose County, Colo.

URANIUM-VANADIUM DEPOSITS.

Deposits of uranium and vanadium occur near Richardson, north of the La Sal Mountains, and 27 miles from Cisco, the nearest railroad point on the Denver & Rio Grande Railroad. Some ore has been shipped, but the deposits have not been actively worked for several years.

The ores occur in a breccia zone associated with a strong northeast fracture in sandstones of probable Triassic age.[3] The ore minerals are of various compounds of vanadium, uranium, copper, and arsenic.

Uranium-vanadium deposits have been discovered in the McElmo sandstones at numerous localities around the La Sal Mountains both in Utah and in Colorado. The most extensively developed deposits in Utah are on Pack Creek southeast of Moab, in Dry Canyon and Big Indian Canyon south of the La Sal Mountains, and at several localities between these areas. Deposits are reported from Lisbon Valley,

[1] Hill, J. M., Notes on the northern La Sal Mountains, Grand County, Utah: U. S. Geol. Survey Bull. 530, p. 118, 1911.

[2] Emmons, W. H., The Cashin mine, Montrose County, Colo.: U. S. Geol. Survey Bull. 285, pp. 125-128, 1906.

[3] Boutwell, J. M., Vanadium and uranium in southeastern Utah: U. S. Geol. Survey Bull. 260, p. 203, 1905.

southeast of the mountains. There has been considerable development at Gateway east of the mountains, 15 miles southeast of Thompson, northwest of Dome Plateau, and near Courthouse northwest of Moab.

All deposits in the McElmo formation around the La Sal Mountains show a striking resemblance, though there is some variation in mineral composition. Characteristically they occur as small bodies in sandstones closely associated with fossil plant remains. The metals in these deposits include vanadium, uranium, chromium, copper, and selenium in various mineral combinations. For a discussion of the genesis of the uranium-vanadium deposits see page 155.

MANGANESE DEPOSITS.

Deposits of manganese, in the form of pyrolusite, occur in the sandstone at several localities. From 1901 to 1906 the Colorado Fuel & Iron Co. mined and shipped this material, but under ordinary conditions it was not profitable. During 1916, 1917, and 1918 the high prices caused by the war made mining of these deposits profitable. J. T. Pardee[1] describes the deposits of the Little Grande district as follows:

The manganese ore occurs as irregular lenses or "blankets" that lie a few feet below the surface along the bedding planes of a gypsiferous, calcareous red sandstone near the middle of the McElmo formation (Jurassic?); as veins and nodular concretions along joints below the blankets; and as fragments in the soil, residual from the weathering of ore of the two forms first mentioned. In the area examined the rocks dip but a few degrees from the horizontal and the surface trace of the manganiferous stratum is therefore a very sinuous line, winding around mesas, cliffs, and canyons. From a point near Green River the outcrop of the manganiferous beds runs in general southeastward about 25 miles and thence apparently swings northeastward around the La Sal Mountains. A manganiferous bed is reported to crop out at many places from Green River westward to and beyond the San Rafael swell.

Manganese occurs rather persistently along the part of the bed that was examined, but only in places is it pure enough or in bodies large enough to be considered ore. Few of the blanket deposits are more than 50 feet long and most of them measure 20 feet or less. Generally they are closely spaced for a mile or two, forming rich or workable areas that are separated by long, barren stretches. Ordinarily the workable blankets range in thickness from 2 to 6 inches, but a few reach a thickness of 3 feet.

Loose fragments of ore are scattered over thousands of acres, but owing to variations in their distribution and in the proportion of fragments of rock mixed with them only comparatively small areas are workable under present conditions. In places the fragments of ore, most of them about as big as a walnut, completely cover the ground and can be easily raked up and loaded in wagons. Ordinarily, however, in the workable areas, the fragments are distributed through a foot or less of sandy soil, the completely disintegrated matrix of the original ore bodies. This dry screening ground will yield 10 to 100 pounds or more of ore a square yard but generally not more than 25 pounds.

The bulk of the ore has the properties of pyrolusite, which, as suggested by commonly occurring crystal forms, is probably secondary or pseudomorphic after manganite. Wad is widespread but not abundant, and rhodochrosite occurs sparingly in two mines.

Many of the blanket deposits appear to be almost pure manganese dioxide. Several carloads have been shipped that carried 70 to 85 per cent of manganese dioxide, the principal impurities being lime and silica. The ore generally contains less than 1½ per cent of iron, very little phosphorus, and, rather curiously, from a trace to one-half of 1 per cent or more of copper. In places the blankets grade into material consisting largely of lime and gypsum. The nodular concretions and irregular replacements along joints contain more silica than the ore of the blankets. The residual ore in the soil generally contains 40 per cent or more of manganese, from 8 to 15 per cent of silica, and less than 2 per cent of iron. An average of 35 car samples of mixed ore shipped from the C. F. & I. mine contained 41.3 per cent of manganese, 10.6 per cent of silica, and 1.5 per cent of iron.

It is interesting to record the fact that celestite (strontium sulphate) occurs in nonpersistent beds, from 1 to 6 inches thick, associated with gypsum in the manganiferous stratum at several places in the C. F. & I. mine.

The manganese, lime, and gypsum were originally deposited in a body of water during the Jurassic period, and after the region had been uplifted, and the manganiferous stratum uncovered by erosion in late Tertiary time the ore bodies that are now exploited were formed by the action of surface waters. It is not clear whether concentration of the manganese is still in progress.

Most of the mines in this district were operated part of the time during 1916 and 1917. At present (October, 1918) three operators are producing 400 to 600 tons of high-grade manganese ore a month. Most of this ore comes from the C. F. & I. and Salt Wash mines, operated by the Green River Mining Co. The other active operators are The Needles Mining Co. and J. B. Fouder.

The deposits are worked solely by open pits. The bedded deposits (blankets) bear an overburden ranging in thickness from a few inches to 6 feet, which is stripped off by hand or with plow and scraper. It is rarely profitable to mine them by drifting under cover or to remove more than 6 feet of overburden. Residual fragments of manganese ore are separated from the soil by dry screening and hand picking.

At the C. F. & I. mine a revolving screen driven by a gasoline engine has been discarded for one-man hand-shaking screens and stationary sloping screens such as are

[1] Manganese in the Green River district, Utah: U. S. Geol. Survey Press Bull. 384, pp. 2-3, October, 1918.

commonly used by mortar mixers to clean sand. In this way one man can produce from 1,000 to 2,000 pounds of ore a day. The quantity of ore produced from the blankets by one man is variable but averages nearly the same as that obtained from the residual deposits.

It is estimated that 7,300 tons of high-grade ore (containing more than 40 per cent of manganese) is available for mining under present conditions and without modification of existing methods. Most of this may be classified as "furnace" ore, though a considerable part of it could be hand sorted to "dioxide" ore. About two-thirds of the quantity estimated is contained in the blankets and the remainder in the residual deposits. The above estimates include 20 mines, 2 of which supply more than half the total.

In addition, 22,500 tons, chiefly in the residual surface deposits, are possibly available to mining under improved conditions or methods. Some way other than hand-picking should be devised to separate the rock fragments from the ore.

Under present conditions the ore in the Green River district that contains much less than 40 per cent of manganese can not perhaps be mined profitably, but such ore happens to be not very abundant. About 5,000 tons of ore containing from 15 to 40 per cent of manganese and considerable lime is available for mining. In addition, there is a considerable amount of ore containing smaller percentages of manganese and much silica, most of it in some abandoned claims at the locality known as Court House.

Manganiferous iron ore was observed at only one place, where an outcrop promises to yield several hundred tons of apparently low-grade material. The iron oxides are generally distinct from the manganese and occur chiefly in the layer next below it, but no material rich enough to be classified as iron ore was seen.

The total production of manganese ore prior to 1910 is given by Harder[1] as 3,815 tons, the largest production being made in 1901 and smaller outputs in 1903, 1904, and 1906.

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[1] Harder, E. C., Manganese deposits of the United States: U. S. Geol. Survey Bull. 427, p. 275, 1910.

ABAJO (BLUE) MOUNTAINS.

By B. S. BUTLER.

M. R. Thorpe spent part of the summer and fall of 1915 in studying the Abajo Mountains and presented the results of his work to the faculty of Yale University in partial fulfillment of the requirements for the degree of bachelor of philosophy. Mr. Thorpe has kindly allowed the writer to make the following notes from this material. Those especially interested in the region are recommended to consult the complete report.

GEOGRAPHY.

The Abajo Mountains are in eastern San Juan County. Monticello, the nearest settlement, is about 6 miles northeast of the mountains; Grayson is about 20 miles south; Moab is about 70 miles north; and Thompsons, on the Denver & Rio Grande Railroad, is about 40 miles farther north. Dolores, Colo., on the Denver & Rio Grande narrow-gage railroad, is 60 miles east of Monticello. From Thompsons to Moab the wagon road is good, and from Moab to Monticello it is fair and is being improved. This route is used by the mail stage and for freighting most of the supplies for the region.

The Abajo Mountains are relatively high, and in consequence the winters are cold and the summers only moderately warm. Precipitation is above the average for the Plateau region and a rather abundant forest growth clothes the mountains. Several streams, which head in the mountains and flow across the surrounding plateau till the water disappears, are utilized for irrigation, which, with dry farming, has been practiced with success. The mountains and surrounding plateaus furnish range for cattle, sheep, and horses, and stock raising is the most important industry of the region.

The Abajo Mountains form a typical roughly circular laccolithic mountain group which rises

abruptly from the surrounding plateau to elevations of 10,000 to 11,000 feet or 3,000 to 4,000 feet above the plateau. The streams, which radiate from the mountains, drain to Colorado River through San Juan and Grand rivers.

GEOLOGY.

The sedimentary rocks, which cover most of the area, range in age from Triassic to Cretaceous. The lowest formation extensively exposed around the mountains is the Vermilion Cliff sandstone, which is cut by canyons to the north and west; it has a thickness of 250 to 300 feet. Overlying it is 75 to 100 feet of shales and sandstones, which is overlain by the White Wall sandstone with a thickness of 300 to 400 feet. Above the White Wall sandstone is the McElmo formation of 500 to 600 feet of red and green shales and rather massive beds of light-colored sandstone. This is exposed on all sides of the mountains except the northwest. Overlying the McElmo are Cretaceous rocks (about 200 feet of Dakota sandstone and an equal thickness of Mancos shale), which nearly surround the mountains and extend well up toward the summits.

In the central portion of the Abajo group are exposed several laccoliths, which were intruded at different horizons in the Triassic and the Cretaceous rocks. The rocks are rather fine grained porphyries of monzonitic composition that closely resemble those of the other laccolithic mountains of the Plateau region. A few dikes cut the laccoliths and the adjacent sedimentary rocks.

The sedimentary rocks near the contact with the laccolithic bodies have undergone some metamorphism, the sandstone being changed to quartzites and the shales to hornfels. Locally considerable pyrite has been introduced into the sedimentary rocks near the contact.

The structure is laccolithic, the sedimentary rocks having been raised and arched over the intrusive rocks. The numerous laccoliths intruded at different horizons, together with the influence of earlier structural features, has, however, caused the structure to vary somewhat from the typical.

ORE DEPOSITS.

The first metal discovered in the Abajo Mountains was placer gold. In 1893, following the San Juan "boom" of the previous year, placer gold was found on Johnson Creek. This discovery produced considerable excitement, but very little gold was extracted and the placers were soon abandoned. Shortly afterward prospecting for lode deposits was undertaken and is still continued. Much money and labor have been expended in development and in mill building; but little metal has been recovered, and no deposit has paid the expenses of operation.

Most of the work has been done on mineralized areas near the contact of the intrusive and sedimentary rocks, near which considerable pyrite and some gold have been added in places to the sedimentary rocks.

WHITE CANYON REGION.

By B. S. Butler.

GENERAL FEATURES.

In the White Canyon region are included White Canyon and areas to the north and south that are said to contain some mineral deposits. White Canyon joins the Colorado from the southeast, at Hite, Utah. The region is reached from the north from the town of Green River on the Denver & Rio Grande Railroad by way of Hanksville and Hite and from the southwest from Bluff, on San Juan River. A wagon road from Green River has been built as far as Hite. At Dandy Crossing, just above Hite, animals can easily swim the river, and supplies can be taken across in boats. From Hite the trail, which was once used as a wagon road and which is still an excellent pack trail, passes through White Canyon to the Natural Bridges,[1] 40 to 45 miles distant, and thence to Bluff.

Topographically the region is typical of the plateau country. White Canyon is a deep cut in the gently inclined rocks, whose harder strata form nearly perpendicular cliffs, topped by benches worn back in the weaker rocks. Such a bench, a few rods to half a mile in width, formed on the surface of the massive white Carboniferous sandstone, borders the inner canyon for nearly its entire length and furnishes an easy road. This bench is bordered by nearly unscalable cliffs.

[1] Cummings, Byron, The great natural bridges of Utah: Nat. Geog. Mag., vol. 18, pp. 190-204, 1907; vol. 21, pp. 156-167, 1910; Colossal natural bridges of Utah, idem, vol. 15, pp. 367-369, 1904; Century Mag., August, 1904.

The inner canyon in the white sandstone is in most places very steep and narrow and can be crossed in few places. In the vicinity of the Natural Bridges it is particularly rugged and picturesque and is especially interesting, both because of the scenery and of the ruins left by the prehistoric inhabitants.

Perennial water supplies are scarce and of rather poor quality. The largest supply, so far as the writer is aware, is at Fry's cabin, when a small stream is said to persist through the year. Early in the spring and late in the fall good water can usually be found in the shallow "tanks" that have been eroded in the massive sandstone. Many of these are inaccessible to the cattle ranging in the canyon, and the water is unpolluted. Water holes are also present in the canyon, but the water is of poorer quality. Good timber is lacking, but cedar and other scrubby trees and sagebrush afford fuel for travelers.

The canyon furnishes range for cattle, but no other use is made of the land, and cultivation on an important scale is not possible. The nearest source of farm supplies is the Henry Mountains region and small areas of irrigable land near Colorado River. From the east supplies can be obtained from Bluff on San Juan River, or Grayson and Monticello, at the base of the Abajo Mountains.

GEOLOGY.

STRATIGRAPHY.

The lowest rock exposed in White Canyon is a massive cross-bedded gray sandstone, several hundred feet of which has been cut through in the upper part of the inner canyon without exposing the base. Above this gray sandstone is 300 to 400 feet of red sandy shale with intercalated beds of sandstone. About 100 feet below its top is a lenticular bed of fossiliferous gray sandstone, in which most of the ore deposits are supposed to occur. Overlying the red shale is a white sandstone that in places attains a thickness of 50 feet but that is distinctly lenticular, nearly pinching out for considerable distances. This sandstone contains small lenses of rather fine conglomerate. Where examined, south of Fry's cabin, it consisted of about 6 feet of conglomerate at the base, overlaid by 15 to 20 feet of sandstone.

Above the white sandstone is a red shaly formation at least 200 feet thick. This in turn is followed by massive red sandstone regarded as Vermilion Cliff sandstone.

The formations exposed in White Canyon seem to correspond to the Aubrey sandstone, Shinarump group, and Vermilion Cliff group of Gilbert's Henry Mountains section.

The following table shows the probable correlation with the Henry Mountains section:

Correlation of Henry Mountains and White Canyon sections.

	Henry Mountains.		White Canyon.
		Feet.	
Triassic.	Vermilion Cliff.		Sandstone.
	Variegated clay shale.	300	Upper red shale.
	Shinarump conglomerate.	30	Gray sandstone and conglomerate.
Permian (?).	Chocolate shale, in part sandy.	400	Lower red shale.
Pennsylvanian.	Aubrey.		Lower white sandstone.

STRUCTURE.

The structure of the region is simple. In passing southeast up the canyon from Colorado River to the vicinity of the Natural Bridges, a distance of about 30 miles in a direct line, the lower white sandstone rises from an elevation of about 3,500 feet (below the surface of Colorado River) to fully 6,000 feet, an average of about 100 feet to the mile. The impression gained in going up the valley is that of a great dome structure or very broad anticline. Southeastward from the Natural Bridges the strata are nearly horizontal for several miles and then dip eastward, at first gently and then pronouncedly near Comb Wash. The region constitutes a broad uplift with relatively steep dips along the easterly margin and gentle, rather uniform dips along the west margin to Colorado River. (See Pl. IV.) This uplift extends from the vicinity of the Abajo Mountains through the Orejas del Oso (Bear's Ears) to Monument Valley and thence into Arizona. Holmes [1] describes the region south of the Abajo Mountains as follows:

[1] Holmes, W. H., Geology of the Sierra Abajo and west San Miguel Mountains: U. S. Geol. and Geog. Survey Terr. Tenth Ann. Rept., 1876, pt. 1, pp. 190-191, 1878.

On the east the Bear's Ears Plateau ends in a great monoclinal fold, with the downthrow on the east. The Cretaceous floor of the Sage Plain extends westward to the line of this fold and occupies about the same absolute horizon as the middle portion of the Triassic formations to the west. The throw of the fold would therefore be approximately 1,000 feet. Although the amount of displacement is so slight the fold is easily traced by a number of monoclinal valleys that follow its axis from the base of the Abajo group to the San Juan. The ridges that separate these valleys have smooth, sloping faces to the east, and one of them, which presents a continuous line of white or pinkish faces, can be traced south to the San Juan, and far beyond into Arizona. Macomb and Epsom creeks on the north, and the Rio de Chelly on the south, occupy the more prominent of these valleys.

Woodruff[1] has described a sharp fold along the eastern border of the San Juan oil field. The outcrop of the La Platz and Vermilion Cliff sandstones along this fold forms the Comb Wash Reef.

A gentle anticlinal fold, or "warp," which trends approximately along the axis of White Canyon nearly at right angles to the larger uplift, dips very slightly to the north and several degrees to the south.

There is little faulting in the canyon, though there are some fissures, along some of which there has doubtless been slight movement.

ORE DEPOSITS.

DEVELOPMENT.

Copper deposits have been known in White Canyon for several years, but owing to the remoteness of the region prospecting has been slight. The unusually high price of copper in 1906 and 1907 stimulated prospecting, and in 1907 a reduction plant was in transit from Green River to Fry's cabin in the upper part of the canyon when the financial troubles of that year put a stop to the undertaking. From 1907 to 1913 but little work was done beyond that necessary to hold the unpatented claims. Some ore was shipped in 1916.

The deposits are typical of those in sandstone throughout the Plateau region. They occur principally in the lenticular white sandstone about 100 feet below the top of the lower shale series.

MINES.

The Dolly Varden claim, about 9 miles from Hite, contains the most extensive deposit so far developed. The copper minerals impregnate the lower part of the white sandstone on the south side of the canyon for a maximum thickness of 15 to 20 feet. The main mineralized zone is on a ridge and is exposed on two sides. About 200 to 250 feet from the point of ridge in a southerly direction the mineralized rock diminishes in thickness to 1½ to 2 feet, and within about 400 feet it disappears entirely. Westward it can be followed for a greater distance, but 300 to 400 feet away it becomes very thin. A tunnel driven in the copper-bearing formation in the most promising part of the outcrop for about 200 feet shows considerable copper in the first 125 feet but little in the last 50 feet. The area of greatest mineralization is cut by fissures that trend N. 70°–90° W. They show little displacement. Along them and extending from them into the bedding is a deposit of black mineral cementing the grains of sand, and with this is some copper carbonate. The black mineral was tested in the Survey laboratory and found to contain considerable cobalt and is probably some form of cobalt oxide. Its composition was not recognized in the field and no accurate data on the amount present were obtained.

The beds are irregularly mineralized, some small lenses containing a rather high percentage of copper, but taken as a whole the ore is of rather low grade. The richest ore observed is in a lens of rather fine conglomerate with a maximum thickness of about 6 inches.

Much of the ore is associated with plant remains, the original copper minerals evidently having partially replaced or having been precipitated by the vegetable matter.

The metalliferous minerals at the surface are mainly carbonates of copper, hydrated oxide of iron, and a black cobalt mineral. Sulphides, which were observed in a few pieces of ore from the dump, consist of cores surrounded by oxidized minerals. In polished sections they are seen to consist of bornite that has been partly, and in some specimens almost entirely, replaced by chalcocite. No chalcopyrite was observed. This fragmentary evidence indicates that the original form of the copper was bornite.

Blue Dike prospect.—The Blue Dike prospect is a mile west of Fifteenmile Crossing, 15 miles from Hite, on the south side of White Canyon. The copper occurs in a lens of white cross-bedded sandstone interbedded with the red

[1] Woodruff, E. G., Geology of the San Juan oil field, Utah: U. S. Geol. Survey Bull. 471, pp. 76–104, 1912.

shale and sandstone series at or near the horizon of the Dolly Varden prospect.

The lens of sandstone is 12 to 15 feet thick, but the copper-bearing rock in the thickest portion is about 10 feet and thins to zero. The mineralized portion is exposed for 150 to 200 feet along the strike. There is a slight seepage of water from the rock, and everywhere the mineralized outcrop is covered by an abundance of efflorescent salts ranging in color from white to varying shades of blue, green, pink, and yellow. The salts are hydrous sulphates, probably of varying composition. The green and blue minerals contain copper; the yellow salts were tested in the Survey laboratory and found to be sulphates of uranium; and the pink salts give tests for cobalt. As yet no thorough chemical or mineralogic study of these salts has been made.

A little water collected in the bottom of a short tunnel was strongly acidic and contains sufficient copper to plate a knife blade in a few minutes. The walls of a tunnel that extends about 40 feet into the ledge are everywhere coated with the efflorescent salts.

A short tunnel driven in the ledge for assessment work in the fall of 1914 revealed sulphides, in large part as a replacement of plant remains and in lesser amount as a cementing material between sand grains. The sulphides noted are chalcopyrite, covellite, chalcocite, and a little pyrite. The chalcopyrite and pyrite appear to have been the earliest of the sulphides and to have been partly replaced by covellite, which in turn was partly altered to chalcocite, the latter mineral being present in relatively small amount in the specimens examined.

In the replacement of the vegetable matter the cellular structure is preserved and is brought out rather prominently when the chalcopyrite alters to covellite. (See Pl. XIV.)

Oxidized copper minerals and a yellow uranium sulphate are associated with all the sulphide exposed. The examination of polished sections failed to reveal any uranium mineral associated with the sulphides from which the sulphate of uranium could have been derived, though the relation is strongly suggestive of the derivation from the sulphides. None of the sulphide was sufficiently free from oxidation products to permit conclusive chemical proof of the presence of other uranium than that contained in the sulphate. There seems little doubt, however, that the iron, copper, cobalt, and uranium were all present in the sulphide ore and that the recognized uranium and cobalt have been derived from the alteration of that ore.

HENRY MOUNTAIN REGION.

By B. S. Butler.

GEOGRAPHY.

The Henry Mountains are an isolated group in Garfield County, southwestern Utah, lying between 37° 40′ and 38° 15′ north latitude and 110° 30′ and 111° west longitude. The group has a northwest-southeast length of about 35 miles and a general width of 8 to 10 miles. Mount Ellsworth, its southernmost peak, is only a few miles from Colorado River. Hanksville, the nearest settlement, is on Fremont or Dirty Devil River, about 15 miles north of Mount Ellen, the most northerly peak, and is about 60 miles by road from Green River on the Denver & Rio Grande Railroad, the nearest railroad point; and is about 150 miles from Richfield, on the Marysvale branch of the Denver & Rio Grande Railroad.

In winter, except on the higher parts of the mountains, the temperature is mild and pleasant, but in summer it is hot. Except on the mountains, the rainfall is light and uncertain. The average rainfall at Hite is given in the table (p. 63).

The plateau around the mountain bears but a scanty vegetation, and in many places overstocking has greatly reduced the normal amount. The result of overstocking is strikingly shown in places where ledges of rock have prevented access of stock to small areas. Such protected areas bear a rather plentiful growth of bunch grass, whereas the accessible areas are nearly stripped of vegetation. The same difference is noted between areas near water and those so remote that stock can rarely feed upon them. The region, if not ruined by overstocking, will furnish grazing for a large number of animals. The higher portions of the mountains bear a rather abundant growth of timber, ample for any uses that seem likely to develop. Gilbert has estimated the forested area as approximately 25 square miles, mostly fir, but including considerable spruce and some yellow pine. Water is not

abundant, but several perennial streams from the mountains suffice to irrigate several hundred acres of land each. At Hanksville several hundred acres are already under irrigation from Fremont River and more can be placed under cultivation. The agricultural output of the region can be considerably increased and seems sufficient to supply any mining communities that are likely to develop. Coal, said to be of fair quality, occurs west of the range but has been very slightly developed.

TOPOGRAPHY.

The Henry Mountains rise 5,000 to 6,000 feet above the general plateau surface, which in the vicinity is approximately 5,000 feet above sea level. The bottoms of the principal canyons are 1,000 to 1,500 feet below the surface of the plateau. The individual mountain peaks are roughly dome-shaped and coalesce at their bases.

Mount Ellen, the northernmost peak, is a somewhat elongated dome with a maximum diameter of about 12 miles, a minimum diameter of 8 to 9 miles, and a maximum elevation of 11,300 feet. Mounts Pennell and Hillers, next to the south, are nearly circular and coalesce at their base. The basal outline of Mount Hillers is about 8 miles in diameter and that of Mount Pennell is considerably less. Mount Pennell reaches an elevation of about 11,000 feet and Mount Hillers slightly less. They are separated from Mount Ellen by a rather high divide (elevation, about 7,000 feet) and from Mounts Holmes and Ellsworth (on the south) by a low divide, which scarcely reaches 5,000 feet.

Mounts Holmes and Ellsworth, the southernmost peaks, are united at their base, and together are scarcely larger than the more northerly peaks. They are each 4 to 5 miles in diameter at the base and slightly above 8,000 feet in elevation.

The range is surrounded by a deeply dissected plateau, which, except along certain lines, is exceedingly difficult to traverse. Close to the bases of the mountains, however, the physiographic development is much more mature, the streams are in shallow canyons, and movement is relatively easy. Gently sloping spurs, some of which are covered with gravel, extend from the base of the range and are evidently remnants of a once continuous surface that has been dissected by streams along its outer margin, and in some places has been largely removed. The surface of these spurs are at an elevation of 7,000 to 8,000 feet. This old dissected erosion bench strongly suggests those surrounding the Abajo, La Sal, and Uinta Mountains, and is probably to be correlated with them, though it is less well preserved.

Other benches at lower elevations evidently represent periods of stability when the streams greatly broadened their valleys. One such bench, 150 to 200 feet above Colorado River, is very conspicuous. It is gravel covered and extends into the side canyons, and evidently marks a level at which the river stood for a long period. Other gravel-covered benches are lower down; and gravel deposits 1,000 feet above the river evidently represent other stages in the development of the canyon. A correlation of these stages with the physiography of the mountains presents an interesting problem, but one that will require detailed work.

The drainage of the mountains is radial from each peak, but at the base it is collected into master streams (Cresent and Trachyte creeks to the northeast and Pine Alcove (Bullfrog) Creek to the southwest), which flow for the most part southeast to Colorado River. The drainage from the north and west side of Mount Ellen is to Fremont River through Lewis and Bowl creeks and thence to Colorado River.

GEOLOGY.

SEDIMENTARY ROCKS.

The sedimentary rocks range in age, according to Gilbert, from Carboniferous to Cretaceous. The following sedimentary section is given by Gilbert:[1]

Section in the Henry Mountains.

	Feet.
Cretaceous:	
Masuk sandstone, yellow, heavy bedded......	500
Masuk shale, gray, argillaceous, and toward the top slightly arenaceous......................	500
Blue Gate sandstone, yellow and heavy bedded.	500
Blue Gate shale, blue-black and argillaceous, weathering to a fine gray clay (*Inoceramus deformis* and *I. problematicus*)...............	1,000
Tununk sandstone, yellow and heavy bedded..	100

[1] Gilbert, G. K., Geology of the Henry Mountains, p. 4, U. S. Geol. and Geog. Survey Rocky Mtn. Region, 1877.

	Feet.
Cretaceous—Continued.	
Tununk shale, blue-black and argillaceous, weathering to a fine gray clay (*Inoceramus problematicus* and *Baculites anceps*)..........	400
Henrys Fork group:	
a. Friable yellow sandstones with numerous fossils * * *..................	10
b. Arenaceous shales, purple, green, and white, with local beds of conglomerate..................................	190
c. Coarse sandstone and conglomerate, with many white grains and pebbles, interleaved with local beds of purple and red shale, and containing immense silicified tree trunks...........	300
Jura-Trias:[1]	
Flaming Gorge group; arenaceous shales or badland sandstones, purple and white at top and red below............................	1, 200
Gray Cliff group; massive cross-laminated sandstone, buff to red in color..................	500
Vermilion Cliff group; massive cross-laminated sandstone, red, with a purple band at the top..	500
Shinarump group; consisting of—	
a. Variegated clay shale; purple and white above and chocolate below, with silicified wood..........................	300
b. Gray conglomerate, with silicified wood; the "Shinarump conglomerate"......	30
c. Chocolate-colored shale, in part sandy..	400
Carboniferous:	
Aubrey sandstone, massive, cross-bedded; base not exposed.	

Gilbert[2] gives the following description of the sedimentary formations:

Cretaceous.—The three upper sandstones, the Masuk, the Blue Gate, and the Tununk, are so nearly identical in their lithologic characters that I was unable to discriminate them in localities where their sequence was unknown. This was especially the case upon the summits of Mounts Ellen and Pennell, where they occur in a somewhat metamorphosed condition. All of them contain thin beds of coal, none of which are continuous over large areas, and only one of which was observed of workable thickness. At the western foot of Mount Ellen a bed 4 feet thick lies at the base of the Blue Gate sandstone.

There is almost equal difficulty in discriminating the Masuk, the Blue Gate, and the Tununk shales. The first is usually of a paler color and is more apt to include arenaceous bands. It has not been found to contain fossils, while the lower shales rarely fail to afford them when search is made. The Blue Gate and Tununk shales are typical examples of fine argillaceous sediments. They are beautifully laminated and are remarkably homogeneous. It is only in fresh escarpments that the lamination is seen, the weathered surface presenting a structureless clay. The fossils of these shales are so numerous, when they have been sought out and studied, that they will probably serve not merely to discriminate the two but also to correlate them with some of the beds which have been examined elsewhere in the Colorado basin. For the present I am unable to refer any of the Cretaceous rocks above the Henrys Fork group to the divisions which have been recognized elsewhere, and it is for this reason that I have given local, and perhaps temporary, names to such beds as I have need to mention in the discussion of the structure of the mountains.

The fossils of the Henrys Fork group have been more fully collected, and they have been referred without question by Dr. White to the group of that name, as recognized in the Green River basin. The white grit which lies at the base of the group is a conspicuous bed of unusual persistence, and is recognized wherever Cretaceous rocks are found in the upper basin of the Colorado.

Jura-Trias.—The rock of the Flaming Gorge group is of a peculiar character. It is ordinarily so soft that in its manner of weathering it appears to be a shale. It is eroded so much more rapidly than the Henrys Fork conglomerate above it that the latter is undermined, and always appears in the topography as the cap of a cliff. Nevertheless, it is not, strictly speaking, a shale. The chief product of its weathering is sand, and wherever it can be examined in an unweathered condition it is found to be a fine-grained sandstone, massive and cross-laminated like those of the Gray and Vermilion cliffs, but devoid of a firm cement. In a number of localities it has acquired, locally and accidentally, a cement, and it is there hardly distinguishable from the firmer sandstones which underlie it. In the immediate vicinity of the Henry Mountains it varies little except in color from summit to base, but in other localities not far distant it is interrupted near the base by thick beds of gypsum and gypsiferous clays, and by a sectile, fossiliferous limestone.

The Gray Cliff and Vermilion Cliff sandstones are often difficult to distinguish, but the latter is usually the firmer, standing in bold relief in the topography, with level top, and at its edge a precipitous face. The former is apt to weather into a wilderness of domelike pinnacles, so steep sided that they can not often be scaled by the experienced mountaineer, and separated by narrow clefts which are equally impassable.

The colors of the two sandstones are not invariable. The lower, which although not reddened throughout its mass is usually stained upon its surface with a uniform deep color, appears in Mount Ellsworth and at other points of elevation with as pale a tint as that of the Gray Cliff. The latter sandstone, on the other hand, where it lies low, is often as deep in color as the Vermilion. Standing upon one of the summits of the Henry Mountains and looking eastward, I found myself unable to distinguish the Gray Cliff sandstone by color either from the lower part of the Flaming Gorge group or from the Vermilion sandstone. The bleaching of the redder sandstone in Mount Ellsworth is probably a result of metamorphism; the reddening of the gray sandstone may depend on the hydration of the iron which it contains.

The thickness of individual strata in these great sandstones is remarkable, and is one of the elements which must be taken into account in the discussion of the problem—which, to my mind, is yet unsolved—of the manner in which such immense quantities of homogeneous sand were accumulated. Ordinarily the depth of strata is indefinable, on account of the impossibility of distin-

[1] Op. cit., p. 6.

[2] Idem, pp. 6-8.

guishing stratification from lamination; but where, as in this case, the lamination is oblique to the stratification, the upper and lower limits of each stratum are definitely marked. I have at several points measured single strata with thicknesses of about 50 feet, and near Waterpocket Canyon a stratum of Vermilion Cliff sandstone was found to be 105 feet thick.

One other measurement is worthy of record; the inclination which oblique lamination bears to the plane of the stratum in which it occurs appears to have a definite limit. The maximum of a series of measurements made at points where to the eye the dip seemed to be unusually great is 24°.

Carboniferous.—Beneath the Jura-Trias is the Carboniferous. A few hundred feet of its upper member, the Aubrey sandstone, are exposed near the summit of Mount Ellsworth. At that point the sandstone is altered to the condition of a quartzite, but where it is cut by the upper and lower canyons of the Dirty Devil River it is massive and cross-laminated, differing from the Gray Cliff sandstone chiefly in the abundance of its calcareous cement.

The following table shows the probable correlation of the formations of the Henry Mountains with those of southwestern Colorado:

Correlation of formations in Henry Mountains with those of southwestern Colorado.

Age.	Southwestern Colorado.		Henry Mountains (Gilbert).
Cretaceous.	Mancos shale.		Masuk sandstone. Masuk shale. Blue Gate sandstone. Blue Gate shale. Tununk sandstone. Tununk shale.
	Dakota sandstone.		Henrys Fork group.
....			
Jurassic.	McElmo formation.		Flaming Gorge group.
	La Plata sandstone.		Gray Cliff group.
Triassic.	Dolores formation.		Vermilion Cliff group.
Carboniferous.	Permian(?).	Cutler formation. Rico formation.	Shinarump group.
	Pennsylvanian.	Hermosa formation.	Aubrey sandstone.

According to Gilbert the sedimentary series shows no unconformity of dip, but erosional unconformities are determined at the top of the Aubrey group, beneath the Shinarump conglomerate, and at the base of the Vermilion Cliff. No unconformity is recognized at the close of the Jurassic, but the presence of such a break at other localities in the Plateau region and the presence of a conglomerate member at the base of the Cretaceous suggest such an unconformity.

IGNEOUS ROCKS.

PETROGRAPHY.

A collection of the typical igneous rocks was made by Gilbert, and a microscopic description by C. E. Dutton was published in his report.[1] Later descriptions of the rocks were published by Cross.[2] The writer was unable to make a systematic study of the rocks, and the following statements concerning their petrographic character are taken principally from the publications named.

Intrusive rocks occupy the central portion of the mountain masses in all the peaks of the group. In Mount Hillers the higher portion of the peak is composed almost entirely of igneous rock, and in most of the other peaks, though sedimentary rocks are more abundant even in the higher portions, they are cut by numerous intrusive bodies. A few intrusive bodies outcrop on the flanks of the group. One, which caps a butte south of Trachyte Creek and northeast of Mount Hillers, might readily be mistaken for a lava flow but has been shown by Gilbert to be intrusive and has been described by him as the Howell laccolith.

The typical rock of the larger masses, so far as observed by the writer, is a gray rather fine grained granitic rock that shows distinct phenocrysts that are rather prominent on the weathered surfaces. The prevailing phenocrysts are plagioclase, those of hornblende are much less numerous; and some of magnetite and titanite can be readily detected with the hand lens. Float was observed at several localities where the porphyritic character was much more pronounced. The porphyritic crystals being large and the groundmass rather fine, the relation of

[1] Gilbert, G. K., op. cit., p. 16.

[2] Cross, Whitman, Geology of Leadville: U. S. Geol. Survey Mon. 12, pp. 359-362, 1886; The laccolithic mountain groups of Colorado, Utah, and Arizona: U. S. Geol. Survey Fourteenth Ann. Rept., pt. 2, p. 175, 1893.

this "bird's-eye porphyry" to the normal porphyry was not observed. In some of the smaller dikes and sills the groundmass is very fine grained and the porphyritic character of the rock is more pronounced, the color is much darker, and the rocks resemble a dense lava and are sometimes mistaken for eruptive rock, as in the case of the Howell laccolith.

Mineralogically the rocks show a marked resemblance througbout and are doubtless to be considered as of a common type. Dutton designated the rocks as trachytes, but their mineral composition is typical of the type now called quartz monzonite or granodiorite, and they may be properly called quartz monzonite porphyry, though some of the rock corresponds more nearly to granodiorite porphyry.

The following petrographic description of the rocks was written by Cross[1] from a study of the specimens collected by Gilbert:

The rock collection made by Gilbert is now represented in the United States National Museum by specimens from about 30 different masses. They represent large and small laccoliths, sheets, and dikes, and come from all parts of the group. As a rule but one specimen was collected from each mass, but the uniformity of these rocks is so great that in most cases the average of the mass is no doubt fairly represented by the single specimen.

As was indicated by Dutton's examination, there is practically but a single rock type. It is a holocrystalline porphyry, characterized by phenocrysts of plagioclase, with hornblende or augite, and by a granular groundmass consisting chiefly of orthoclase and quartz. Its granular equivalent would be a quartz-bearing diorite, and its lava form would be andesite, approaching dacite in some cases. The rock is what has hitherto been called porphyrite by American petrographers and by some Europeans.

The group is especially characterized by its uniform porphyritic structure. Among the phenocrysts plagioclase is always the dominant mineral. It occurs in stout crystals usually between 1 and 4 millimeters in length with a few somewhat larger ones. Occasionally the average size is nearly 5 millimeters, but more frequently it is less than 3 millimeters. Hornblende and augite are smaller than the plagioclase in general, with a tendency of the former to develop here and there in prisms 1 centimeter or more in length.

Nearly all of the rocks are hornblendic without either augite or biotite. In four of them augite replaces most of hornblende and in two others is present in subordinate amount. Biotite is a minor constituent of a single rock.

Quartz phenocrysts, always more or less rounded by resorption, were observed in eight rocks, and are no doubt sporadically present in nearly all of them. Orthoclase phenocrysts are developed sparingly in two rocks, but these are not to be compared with the large crystals occurring in some types to be described from other groups.

Garnet appears scattered irregularly through two of the specimens.

The groundmass is typically granular in the great majority of cases, and consists most naturally of quartz and orthoclase. As quartz decreases the evenness of grain diminishes, and in the feldspathic rocks the grains are elongated instead of exhibiting even dimensions. If plagioclase enters into the groundmass it is in microlitic form. The quartz is clear and distinct from the more or less clouded orthoclase, except in the finer-grained rocks. A tendency of the quartz to form rude dihexahedral crystals is often seen. Micropegmatitic structures are entirely absent. In two cases a patch or micropoikilitic structure is imperfectly developed.

The average size of the groundmass grains is between 0.02 and 0.04 millimeter for more than half the rocks. In another large division the groundmass is cryptocrystalline, though never far below the limits of probable identification. The average grain rises above 0.04 millimeter in but three rocks, and never reaches 0.1 millimeter.

The microscopic accessory constituents are apatite, magnetite, and zircon, in the usual development; titanite, very characteristic of a large number; and allanite, seen sparingly in five rocks. Magnetite often occurs in two generations—in large phenocrystic grains and in minute ones belonging to the groundmass.

Distribution of types.—The different mountains and different kinds of occurrences are quite evenly represented in the collection. Eight are from large laccolites, three from small ones, eight from sheets, and nine from dikes.

The augite-porphyrites are all from Mount Pennell or Mount Hillers, but hornblendic rocks apparently predominate in both mountains. The augitic types are mainly from sheets, but it is possible that the main Hillers laccolite is of this rock.

As to the grain of the rocks—the cryptocrystalline forms are all from dikes, mainly in Mounts Ellsworth and Holmes. The average-grained rock occurs in laccolites, sheets, and dikes. The three coarser-grained ones come from dikes or sheets in different mountains.

The observations then confirm the conclusions of Dutton that these specimens indicate no differences of composition or structure corresponding either to geographical or geological distribution or to the size or form of the intruded masses. The collection is of course not large enough to permit of a positive statement that no correspondence between occurrence and characteristics of any kind exists in the Henry Mountains, but it does clearly prove that certain generalizations can not be made.

Three analyses of the intrusive rock of the Henry Mountains are given on page 94.

AGE.

The age of the intrusive rocks from direct evidence can only be determined as later than the Cretaceous sediments which they intrude. No Tertiary sediments are present in the vicinity of the Henry Mountains. From a consideration of the depth at which the laccoliths are supposed to have formed, Gilbert says that "what evidence we have, then, indicates that

[1] Cross, Whitman, Laccolithic mountains of Colorado, Utah, and Arizona: U. S. Geol. Survey Fourteenth Ann. Rept., pt. 2, p. 175, 1893.

the epoch of laccolitic intrusion was after the accumulation of deep Tertiary deposits and before the subsequent degradation had made great progress; that it was at or near the close of the epoch of local Tertiary sedimentation."

METAMORPHISM.

The effect of the intrusive bodies on the adjacent sediments is described by Gilbert as follows:

> Wherever the trachytes came in contact with the sedimentaries the latter were more or less altered. Large bodies of trachyte produced greater changes than small. The laccoliths both metamorphosed their walls more completely and carried their influence to a greater distance than the sheets and dikes. The summits of the laccoliths had a greater influence than the edges, a phenomenon to which I shall have occasion to revert. The sandstones were less affected than the shales, at least in such characters as readily catch the eye. Clay shales were indurated so as to clink under the hammer, and Capt. Dutton discovered with the microscope that minute crystals of feldspar had been developed. Sandstones were usually modified in color, and their iron was segregated so as to give a mottled or speckled appearance to the fracture. They were indurated, but the granular texture was always retained.
>
> The trachyte carries numerous small fragments of sedimentary rock broken apparently from its walls, and these are as thoroughly crystalline as their matrix.
>
> The altered rocks are usually jointed, but nothing approaching to slaty cleavage was seen, nor has there been any crumpling.
>
> The reciprocal influence of the sandstone and shale upon the trachyte was small. Specimens broken from the contact surface of a laccolith and from its interior can not be distinguished. In the Marvine laccolith, however, there is a difference between the exterior and interior portions in their ability to withstand erosion.

On the ridge extending from Mount Pennell toward Mount Hillers rather notable contact alteration was noted. Blocks of shales, shaly sandstones, and apparently some sediments rather rich in lime carbonate are partly inclosed in the monzonite porphyry. The shales have been rather highly indurated, and the calcareous sediments contain abundant contact minerals. Epidote is the most abundant of these; garnet and a green amphibole and probably other silicates are present; and magnetite and specularite occur in small amount. Some pyrite is present, and the rather abundant limonite indicates that it may have been rather plentiful. Small fissures in the monzonite porphyry near the altered sedimentary rocks also contain contact minerals, notably epidote, and the porphyry rock adjacent to the contact contains epidote as an alteration product of other minerals. At several points around the mountains pieces of float containing contact minerals were observed, and it is evident that considerable contact alteration accompanied the intrusion.

STRUCTURE.

The general structural relations of the Henry Mountains are relatively simple. They are laccolithic mountains and are usually referred to as the type of this structure on account of Gilbert's classic description of them, in which the term was first applied, though the general structural relations of such mountains had been ascertained some years earlier from studies of similar mountains in Utah and Colorado.

The simplest form of laccolithic mountain is produced by the intrusion of igneous ma-

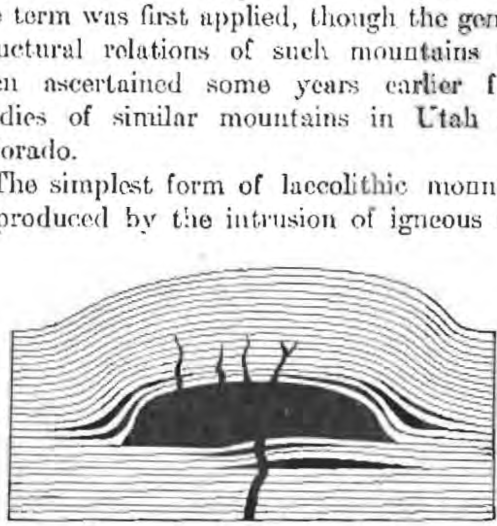


FIGURE 72.—Ideal cross section of a laccolith, with accompanying sheets and dikes. After Gilbert.

terial through a fissure till it reaches a horizon favorable for its extension laterally. Such conditions may result from the presence of a body of shale through which the fissure does not pass. A stratigraphic break may also favor lateral movement. The material moving outward tends to form a body with a circular outline. As more material is added, the pressure from below, transmitted through the fluid mass, lifts the overlying strata to make room for additional material and eventually forms a distinct dome. (See fig. 72.) The arching of the strata would naturally fissure the upper portion of the dome, and the igneous material would occupy such fissures and form dikes such as are common in the mountains of this group, notably in Mount Ellsworth. It is readily seen that though the typical laccolith is of simple structure, the igneous material is likely to spread out at different horizons and to produce a great complexity of laccoliths, sills, and dikes, and such is the case in many places in the Henry Mountains. (See fig. 73.)

The accompanying diagram shows the horizon of the laccolithic bodies of the different peaks and the number that Gilbert determined for each peak.

The peaks, as they exist to-day, are the result of erosion. The igneous rocks forming the laccolithic bodies are more resistant to weathering and erosion than the surrounding

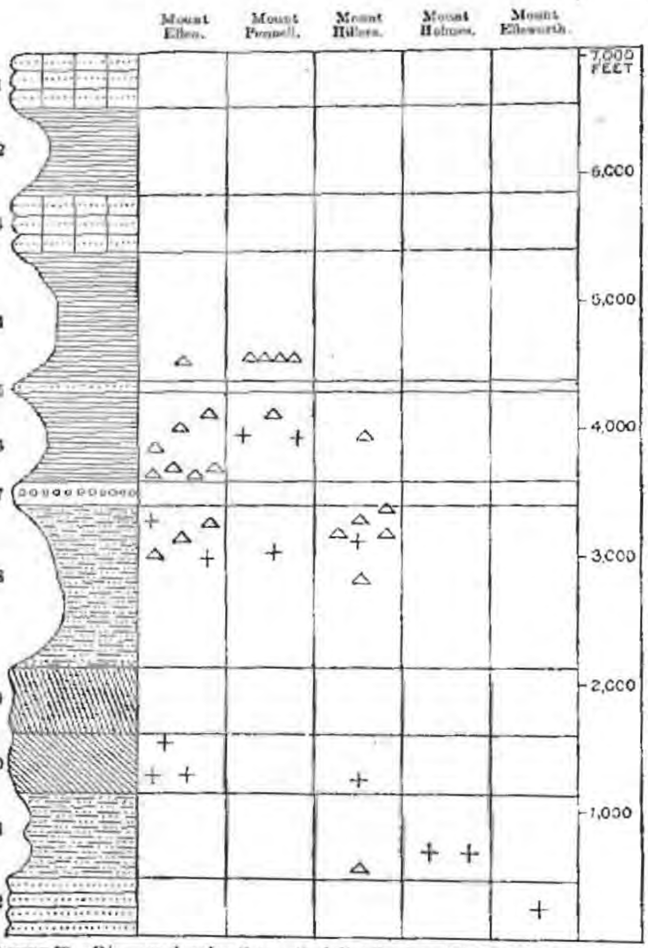


FIGURE 73.—Diagram showing the vertical distribution of the laccoliths of the Henry Mountains. Triangles mark the horizons of determined laccoliths and crosses mark the horizons above which the invisible laccoliths can not rise. After Gilbert. 1, Masuk sandstone; 2, Masuk shale; 3, Blue Gate sandstone; 4, Blue Gate shale; 5, Tununk sandstone; 6, Tununk shale; 7, Henry's Fork conglomerate; 8, Flaming Gorge shale; 9, Gray Cliff sandstone; 10, Vermilion Cliff sandstone; 11, Shinarump shale; 12, Aubrey sandstone.

sedimentary rocks and have consequently worn away less rapidly.

HISTORY AND PRODUCTION.

The first lode deposit to be discovered in the Henry Mountains that proved of any consequence was the Bromide vein, which is said to have been discovered in 1889 or 1890 by the partners, J. C. Sumner and Jack Butler. Active development of the mine was carried on in 1891, and a stamp mill was built and operated intermittently till the following summer. The mine was closed in 1893 and remained idle till 1902, when it was reopened and made a small production. In 1913 it was idle and had been for some time. The finding of the Bromide vein stimulated prospecting in the region, and several small veins were discovered and prospected to some extent. Next to the Bromide the most extensive development has been on the Oro prospect. A one-stamp mill was erected and some ore treated.

Interest in the carnotite deposits of Colorado and eastern Utah resulted in prospecting for similar ores in the Henry Mountains region in 1912, since when numerous deposits of uranium and vanadium ore have been located.

For several years there has been a small gold production from the channel of Crescent Creek and from the benches near its head. Placer gravels along Colorado River near the base of the mountains are described on page 637.

The metal production of the region is not known but has not been large. It is reported that the Bromide mine produced about $15,000 in 1892 and a little more since. The uranium and vanadium ores were shipped from the district in 1913 and 1914, but there has been little shipped since the opening of the war.

ORE DEPOSITS.

DEPOSITS IN OR CLOSELY ASSOCIATED WITH INTRUSIVE ROCKS.

VEINS.

The fissure deposits in the igneous rock are prevailingly gold-copper deposits. The area most extensively prospected and apparently most promising is near the head of Crescent Creek, in the general vicinity of the Bromide and Oro, the only mines that have been productive.

Bromide mine.—The Bromide vein is typical of the group. It outcrops about 9,000 feet above sea level, strikes a little east of north, and dips very steeply west. It has rather well-defined walls, the distance between which varies greatly along both the strike and the dip, in places coming nearly together and in other places separating to a width of 4 feet or more.

Numerous fractures that cross the main vein nearly at right angles appear as a rule to have had little effect on it. There has been slight movement in some of them, and it is said that one small cross vein containing amethystine quartz was rich in gold where it crossed the main vein.

The vein filling is very largely brecciated wall rock that has been slightly altered by the ore solutions, some vein quartz, and a fibrous white mineral, mainly laumontite though possibly containing other zeolites. The principal primary metallic minerals are pyrite, chalcopyrite, specularite, magnetite, and ilmenite. The magnetite and ilmenite may not be true vein minerals but may have been contained in the original quartz monzonite. A sample of mill concentrates contained a large percentage of magnetite, a lesser amount of rather feebly magnetic material, and a residue largely composed of sulphide and copper carbonates. Native gold contributes most to the value of the ore.

The wall rock in and adjacent to the vein has been somewhat altered. The freshest quartz monzonite in the vicinity of the vein shows a slight secondary development of epidote and carbonate and a little pyrite. In the vein the feldspars have been partly sericitized, the hornblende partly altered to chlorite, which has also been deposited in open spaces in small spheroidal masses. The alteration of the wall rock has been in most places comparatively slight. To the depth of the tunnel level the ores have been partly oxidized, the sulphides altering to oxides of iron and carbonate of copper.

The mine has been opened by a tunnel about 330 feet long connecting with a shaft at a depth of about 125 feet. A winze has been sunk 60 feet below the tunnel level. The vein has been developed on the tunnel level for perhaps 200 feet and has been stoped on different levels from the tunnel level to the surface. It is reported that ore is present in the bottom of the winze, but at the time of visit this was filled with water and could not be examined. A crosscut tunnel, started from Crescent Creek near the mill, will, if extended, intersect the downward extension of the plane of the vein about 400 feet below the present tunnel level. The face of the crosscut tunnel was about 900 feet from this objective point in 1913.

Exact figures of the average grade of the ore are not available, but Frank Bennett estimates that the ore milled yielded $10 to $11 per ton on the plates and that an additional amount was obtained from the concentrates. The mine is equipped with a five-stamp mill with amalgamation plates and a Wilfley table.

Cuprum claim.—On the Cuprum claim, a short distance east of the Bromide vein, a magnetite vein strikes about north and stands nearly vertical. Where examined in an open cut it had a maximum width of about 18 inches with small stringers extending through the adjacent quartz monzonite.

The vein mineral is principally magnetite (lodestone) with a small amount of quartz and copper carbonate. A large part of the copper minerals are associated with the quartz and have probably been derived from sulphides that may have been deposited most abundantly with the quartz.

The wall rock has been altered in a manner similar to that of the Bromide vein, though in the specimens examined alteration appeared more intense in the magnetite vein.

The ore is said to carry $4 to $5 per ton in gold, and some of it contains notable amounts of copper carbonate. The ore containing most copper is said to be richest in gold.

Oro mine.—The Oro mine is on the opposite side of Crescent Creek from the Bromide and at a slightly lower elevation. The vein, which strikes nearly north and dips steeply west, is similar to that of the Bromide. It has been developed by several hundred feet of tunnel and a shaft about 70 feet deep. Some ore has been milled at a one-stamp mill on Crescent Creek.

Other claims.—Other veins in the same region are said to be similar in character but have been but slightly prospected. There has been a little prospecting on the east side of Mount Pennell near the head of Straight Creek. The mineralization has been along fracture zones in the porphyry. At the surface it consists principally of oxides of iron and carbonate of copper.

On the Baby Ruth claim small irregular fissures in the porphyry have been prospected. The porphyry is rather fine grained and in the vicinity of the fissures has been slightly silicified. The gold is apparently in small veinlets of limonite that ramify the brecciated por-

phyry. Some of the ore is said to be high grade, but the average is low. An arrastre on Straight Creek about 2 miles below the mine is said to have treated a few tons of ore.

A little prospecting has been done on Mount Hillers. The prospects were not visited by the writer, but from descriptions they appear to be similar to the copper prospects of Straight Creek.

CONTACT DEPOSITS.

A little prospecting has been done in the contact deposits, especially in those on the ridge extending from Mount Pennell toward Mount Hillers. Irregular blocks of the sedimentary rock, mainly shales but in part evidently calcareous, rest on the quartz monzonite. In the calcareous members abundant contact silicates, mainly of a yellow-green epidote but also containing amphibole and garnet, have developed. Pyrite was seen in some specimens, and the amount of limonite in places suggests that sulphides were originally present in considerable abundance. Some of the limonite is said to contain as much as $20 in gold per ton. The contact material at other points is said to contain small amounts of gold.

At the time of the writer's visit several claims had been located for thorium, which was said to occur in the epidote. A sample of this material, however, which was submitted to the chemical laboratory of the Geological Survey, was reported by W. T. Schaller to contain no thorium and no rare earths.

DEPOSITS IN SEDIMENTARY ROCKS.

The most important deposits in the sedimentary rocks are of uranium and vanadium. Minerals containing these elements have been found in sandstones of Gilbert's Flaming Gorge group that are believed to be equivalent to the McElmo formation of western Colorado. The formation outcrops along the eastern side of the mountains from Bowl Creek on the north to a point south of Mount Hillers, passes between Mount Hillers on the north and Mount Holmes and Mount Ellsworth on the south, and extends southwest to Hoxie (Hall) Creek. (See fig. 74.) At numerous localities uranium-vanadium deposits have been found. The northernmost deposit known is about 2 miles south of Gibbon's ranch. Between this and Crescent Creek deposits are reported to have been located, and on Crescent Creek W. Hicks has located several claims. Near Trachyte Creek the Standard Chemical Co. has done a large amount of development work, and in 1914 shipped considerable ore. Four to five miles northwest of Mount Ellsworth the Standard Chemical Co. has also done considerable development and has shipped ore from the Delmont and Lida groups of claims.

The occurrence of these ores is similar to that of radium-bearing ores in sandstone elsewhere in Utah. Most of the minerals are closely associated with carbonized plant remains. Where the plant remains are entirely silicified no deposits were seen. Thus in the rather extensive exposure of the sandstone between Hoxie (Hall) and Pine Alcove (Bullfrog) creeks, and east of the latter, silicified trees are rather plentiful in places, but no uranium or vanadium was noted with them.

Some deposits are confined to a single tree trunk and some form lenses in the sandstone. Such lenses had been followed in on the bedding for 60 to 75 feet (1914), rarely more, but most of them pinch or decrease in value within a much shorter distance.

The mineralogy of the ores is similar to that in other sections. The principal uranium mineral is carnotite. Vanadium is present in the carnotite and as hewettite or metahewettite. An undetermined chromium compound is associated with many of the deposits, and they contain small amounts of selenium.

The origin of the deposits is doubtless the same as that of the similar deposit in Utah and Colorado. (See p. 155.)

Along Colorado River there has been some prospecting of the Triassic sandstone. Small deposits of copper have been found and uranium minerals are reported, but there has been no production of either. These deposits occur at essentially the same horizon as those in White Canyon.

PLACER DEPOSITS.

Placer gravels occur in the bed of Crescent Creek and on benches at higher levels. In 1914 the gravels in the bed of the creek were being sluiced and some dry washing was being done on the higher benches. The presence of gold-bearing gravels in this locality has been known

for several years but they have yielded in all only a few hundred dollars in gold.

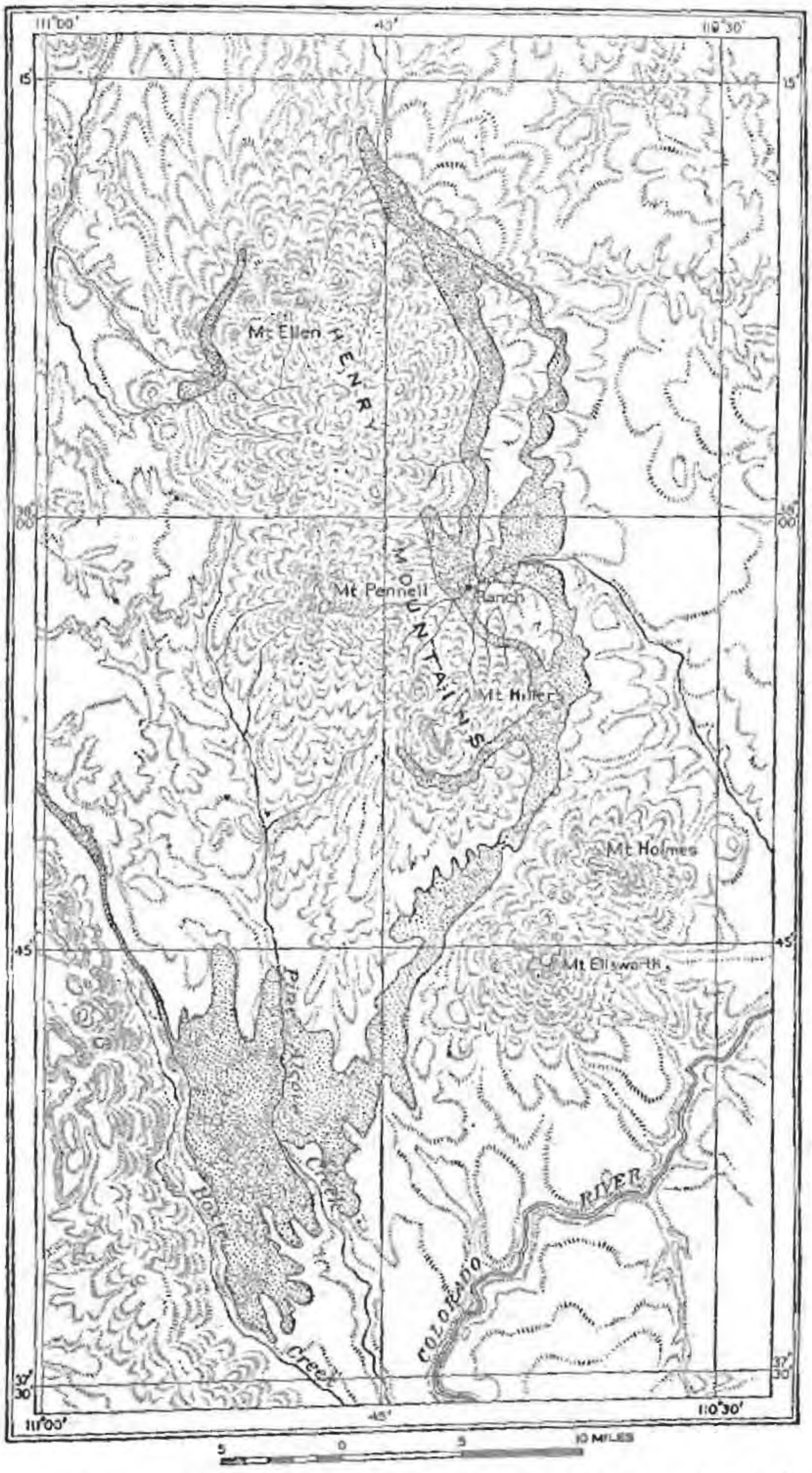


FIGURE 71.—Sketch map showing distribution of the uranium-vanadium bearing sandstone in the vicinity of the Henry Mountains. Prepared by B. S. Butler and W. L. Whitehead.

The gravel on the benches apparently accumulated from the material coming from the mountains before the present canyons were cut. When the streams renewed their downcutting the bench gravels were in part reworked and formed the channel gravels. Barite sand is abundant in the placer gravels and is believed to be derived from veins in the mountains at

the head of Crescent Creek. The placer gravels, so far as known, are confined to Crescent Creek, near whose head the most important gold-bearing veins occur. This relation naturally leads to the belief that the gold of the placers was derived from the gold-bearing veins in the mountains.

MINERS MOUNTAIN.

By B. S. Butler.

Miners Mountain is in the western part of Wayne County, a few miles southeast of the settlement of Torrey and southwest of Fruita. For many years intermittent prospecting for copper has been carried on, and a few hundred pounds of high-grade ore is reported to have been shipped.

GEOLOGY.

The youngest rock in the mountain is an impure, shaly, and sandy limestone about 75 feet thick. This is underlain by 100 to 150 feet of red shaly beds, which in turn is underlain by a massive sandstone having an observed thickness of over 200 feet with the base unexposed. Fossils collected from the limestone were determined by G. H. Girty to be of Lower Triassic age. The underlying shales should probably also be regarded as Lower Triassic, and the sandstone is probably Carboniferous. Surrounding the mountain are the higher Triassic and Jurassic formations.

Miners Mountain consists of an elongated dome-shaped uplift which trends northwest. The surface of the dome is mainly determined by the rather resistant Triassic limestone, but in numerous places this has been cut through by the streams, revealing the underlying red shales and the sandstone.

ORE DEPOSITS.

Prospecting has been carried on mainly on the southeastern portion of the mountain, where deposits of copper and lead have been explored.

The deposits of copper examined by the writer and W. L. Whitehead occur as small lenses in sandstone and shale strata in the red shale series just beneath the fossiliferous limestone. The ores are practically all oxidized, consisting of azurite and malachite associated with considerable limonite. In the development of the deposits several shafts have been sunk to depths of 30 to 50 feet and short tunnels have been driven.

The lead deposits examined occur in the massive sandstone formation, probably 200 feet below the top. A lenticular zone of less massive material between two massive beds of sandstone has been mineralized for several hundred feet along the strike. Limonite is the most abundant of the metallic minerals. With it are stringers and small kidneys of cerusite, and disseminated through it is plumbojarosite in small amount and possibly other sulphates. So far as learned there has been no production from the lead deposits.

The deposits of Miners Mountain are similar to the "red bed" deposits at other localities in the State and doubtless have a similar origin. The genesis of this type of deposit is discussed on page 155.

RABBIT VALLEY.

GEOLOGY.

The domal structure of Miners Mountain extends northwest nearly to Thurber, where the sedimentary rocks are buried beneath volcanic material. The boundary between the sedimentary and volcanic rocks is said by Dutton to mark the site of a great fault. From Thurber to a point a few miles east of Torrey the valley of Fremont River has been cut near the crest of this dome. East of Torrey the stream flows along the northern side of the dome to the point where it breaks through the Water Pocket fold.

The Carboniferous sandstone of Miners Mountain is overlain by red shaly beds and shaly and sandy limestone of Lower Triassic age. Along either side of the mountain and to the north of the valley lie higher Triassic shales with beds of sandstone, and above these the Vermilion Cliff and White Cliff sandstones form prominent cliffs. About 150 to 200 feet below the massive Vermilion Cliff sandstone are two, and in places three, lenticular beds of sandstone that are rather persistent through the region, though at any given locality one or more may be lacking. These contain rather abundant plant remains.

URANIUM DEPOSITS.

Deposits of uranium associated with the plant remains in the sandstone beds were observed near the mill east of Thurber and are

reported from several localities between there and Grand Wash, and thence southward along the west side of the Water Pockets beyond Temple Creek. A little prospecting has been done near the Thurber mill and at other points, but the only place from which there has been production is at the head of Grand Wash, near Fruita (Junction). The sedimentary series at this point follows:

Section near Fruita (Junction).

	Feet.
Massive cross-bedded Vermilion Cliff sandstone.	
Shales, variegated, purple	100
Sandstone, brown	15–20
Peculiar conglomeratic rock composed of concretionary bodies, mainly calcium carbonate in clay matrix, with interbedded limestone	50
Shale, chocolate	20
Sandstone, loosely cemented, gray, with streaks of red and green; contains abundant plant remains.	10–20
Shale, chocolate	30
Sandstone with fossil trees.	
Shale, chocolate	±10
Sandstone, gray	±10
Shale, green and chocolate.	

The Triassic rocks at the head of Grand Wash comprise three sandstones that contain fossil plant remains. The lower has a maximum thickness of 10 feet at Grand Wash but is distinctly lenticular and toward Capital Wash reaches a thickness of 30 to 40 feet. On the Old Dixon prospect, the only prospect from which shipment has been made, uranium minerals occur in a lens containing carbonized plant material. On the opposite side of the wash the fossil material observed was mainly logs and contained little uranium but considerable iron. The second sandstone is rather strongly cemented, contains but few logs, and these are but little mineralized. The upper sandstone is loosely cemented and contains abundant logs, some of which are 3 feet in diameter. The logs are mainly silicified but are commonly surrounded by a thin layer of carbonized material. Outside the carbonized material surrounding the logs and associated with that within the logs are red and yellow minerals, mainly hydrous ferric oxides and sulphates, probably mainly limonite and jarosite. Some of these iron minerals rather strongly resemble uranium and vanadium minerals and are frequently mistaken for them.

The uranium occurs as it does in the Triassic rocks at other localities and is doubtless of similar origin.

NAVAJO MOUNTAIN.

By B. S. Butler.

Navajo Mountain is on the Utah-Arizona boundary, a few miles south of the junction of San Juan and Colorado rivers, in the midst of a rough desert region, remote from railroads and difficult of access. The discovery of a great natural bridge[1] a few miles north of the mountain has attracted a few travelers in recent years; otherwise the district has few attractions.

Topographically, the mountain is a great dome that reaches an elevation of 10,400 feet and is deeply dissected by streams radiating from the summit.

The sedimentary rocks of the mountain are sandstone and shales of Jurassic and Triassic age with a small area of Cretaceous rocks at the summit.[2] Igneous rocks have been generally reported, but Gregory states that none are exposed. The dome structure, however, is interpreted as being due to an underlying igneous mass that has lifted the overlying sedimentary rocks.

As is common with remote and difficultly accessible regions, rich silver and gold deposits in the vicinity of Navajo Mountain have been vaguely rumored. Gregory, however, says that there is little basis for the reports. It should be borne in mind, however, that uranium and vanadium deposits may be found around this mountain, and that some copper deposits of the character common to the Plateau region are known to be present there.

PARIA REGION.

By B. S. Butler.

Paria, in Kane County, has been the scene of some mining activity, mainly for gold, and uranium deposits in Triassic sandstones have been reported from a few miles farther south. No description of the uranium deposits has been published, but they are probably similar to those in the Triassic at other localities in the State.

[1] Cummings, Byron, The great natural bridges of Utah: Nat. Geog. Mag., vol. 21, pp. 156–167, 1910. Pogue, J. E., The great Rainbow Natural Bridge of southern Utah: Nat. Geog. Mag., vol. 22, pp. 1048–1056, 1911. Roosevelt, Theodore, Across the Navajo Desert: The Outlook, Oct. 11, 1913, pp. 309–317.

[2] Gregory, H. E., Geology of the Navajo country: U. S. Geol. Survey Prof. Paper 93, map, 1917.

GEOGRAPHY.

The writer has not visited Paria, but an account of the region, quoted in large part below, has been published by A. C. Lawson.[1]

Paria is a settlement on a flood plain of the Paria River now consisting of one family, which maintains a post office for the convenience of the sheepherders of the region. It is situated about midway between Lees Ferry at the head of the Marble Canyon and Canyonville in southern Utah. To the north and south of Paria the river flows through a narrow canyon with precipitous walls, but at Paria the course of the stream is in the Shinarump clay for about 3 miles; and in this stretch it has, by horizontal corrosion, evolved a conspicuous flood plain having a maximum width of about half a mile. On the northeast side of the flood plain the Shinarump clay forms a buttressed pedestal about 400 feet high, upon which rests the massive bright-red sandstone of the Vermilion Cliff. The total height of the scarp is probably about 800 feet and its upper half is vertical. The lower half of the scarp, forming the pedestal, is a curiously sculptured slope having a width at the southeast near Paria of from 400 to 500 feet, but widening toward the northwest to about 3,000 feet. The slope is dissected by numerous steep gulches which head up to the base of the vertical cliff; and these have tributary gulches. The areas bounded by the drainage lines of these gulches are shaped in smooth, steep-sided, bare domes. The surface of the slope is thus remarkably mammillary, and presents a type of erosional form which is quite characteristic of the Shinarump, although it has been scarcely alluded to in numerous descriptions of the physiography of the Plateau province. * * *

On the southwest of the Paria flood plain the Vermilion Cliff sandstone has been removed, except for one isolated butte about 40 acres in extent; and the relief is determined by the peculiar mammillary or domed forms of the Shinarump clay. The breadth of the clay on this side of the river is about 4,000 feet. At its southwestern margin the clay is seen in fine exposures to rest upon a light-gray sandstone, with a gentle northeast dip. This sandstone, being more resistant than the clay, projects generally beyond the limit of the latter as a well-defined backward-sloping bench.

To the southwest of the Shinarump extends the Permian, the upper surface of which forms a gently sloping plateau on the flank of the East Kaibab monocline. The plateau is intricately dissected by innumerable narrow vertically walled canyons, so that it is practically impossible to traverse it. Still farther to the southwest, this sloping plateau of Permian strata ends at an escarpment overlooking the top of the Aubrey limestone as it bends up in the great monocline.

GEOLOGY.

In the Plateau province he who runs may read the sequence of formations. In my own case the pleasure of the reading was drawn out in a leisurely walk of 80 miles from Lees Ferry to Paria by way of House Rock Valley. Along this route the great roll of the East Kaibab monocline is splendidly revealed in the surface of the Aubrey limestone, where it has been stripped of its covering of Permian and later strata. In the descent from the head of House Rock Valley to Paria the Permian is exposed from top to bottom in the winding canyon followed by the wagon road. It consists of several hundred feet of thinly bedded red-mud shales and sandy shales. In its lower and middle part the strata are traversed by innumerable narrow gash veins of gypsum. These range usually from an inch to an eighth of an inch in thickness, and lie nearly flat, but generally at a small angle with the bedding. * * *

In the upper 200 to 300 feet of the Permian section the gypsum veins are not notable features of the canyon walls. The latter are variegated in color, however, by the intercalation of thin beds of green shale with the prevailing red beds. The green beds make up about 10 per cent of this portion of the Permian section. The uppermost bed of the Permian is distinct from all below it in that it is a persistent stratum of hard, massive red-brown sandstone from 10 to 20 feet thick.

Resting on the Permian is the basal formation of the Shinarump group. The superposition is well exposed along a northwest-southeast line of contact less than a mile southwest of the Paria River at Paria. The basal formation is from 30 to 50 feet thick and is a rather coarse-textured light-gray sandstone, which is in some parts pebbly, and which contains numerous fragments of silicified wood. The stratigraphic relation of sandstone to the underlying Permian is described by Walcott[2] as unconformable. The erosional break figured by him is very plain at one locality, but as he points out it involves no essential discordance in the dip of the two formations; so that it is not easily detected elsewhere.

The clays of the Shinarump which rest on this basal sandstone are the most interesting feature of the section. They have a maximum thickness of about 400 feet on the northeast side of the Paria but appear to be considerably less than this in the section through the butte on the southwest side, where the complete section of the beds between the Permian and the Vermilion Cliff sandstone is revealed.

The stratification of the Shinarump clays is not less remarkable than their erosional forms. Viewed at a distance the formation is seen to consist of thick layers of different colors sharply marked off one from another. One or two beds of sandstone occur in the sections, but with this exception the diversely colored layers are homogeneous as to texture and resistance to erosion; so that the bedding planes do not mark any break or interruption of the profiles of the domes into which the whole formation has been carved. The colors of the beds have been subdued by weathering, so that the strong deep tones seen in fresh cuts appear as faded and harmonious tints on the natural slopes. The general effect is that of a pleasing gray relieved by thick horizontal bands of pink, chocolate, maroon, green, purple, black and white; but the gray tints prevail in the lower part of the section and the reddish tints in the upper part. * * *

Three sections of the Shinarump clays were examined in great detail by cutting trenches in the face of the slopes. One of these was chosen on the northeast side of the Paria flood plain, one on the southwest side, and the third on the southwest margin of the formation where it overlooks the

[1] Lawson, A. C., The gold of the Shinarump at Paria: Econ. Geology, vol. 8, pp. 434-446, 1913.

[2] Geol. Soc. America Bull., vol. 1, pp. 63-64, 1890.

Permian plateau. The sections were thus about half a mile apart and on a line transverse to the strike of the formation.

The first-mentioned trench was a continuous cut from the level of the river up to a point 210 feet above it across the edges of the strata in the middle part of the formation. The second was similarly cut from the level of the river across 174 feet of the lower part of the formation. The third was cut from the top of the basal sandstone across 240 feet of the clays, or about two-thirds of the total thickness in this section. The measurements of the beds in these trenches afforded an exact section of the Shinarump as far as they extended, but as the measurements had to do merely with color distinctions, the character of the beds being for the most part otherwise identical, I shall here refer only to certain special features. In the most southwesterly section a 2-foot bed of light-gray medium-textured sandstone was encountered interrupting the continuity of the clays at 110 feet above their base. Above this the clays are sandy for several feet. Half a mile to the northeast, in the middle section, a bed of similar sandstone 15 feet thick occurs, the base of which is 125 feet above the Paria flood plain. Half a mile to the northeast, in the remaining section, this same bed of sandstone has expanded to a thickness of 50 feet of soft sandstone with a layer of 2 feet of hard sandstone at its base. Above the 50-foot bed of sandstone, after an interval of 9 feet of red and purple clays, is another bed of sandstone, 4 feet thick, which is much harder than the thick bed below. Along the northeast side of the Paria these sandstones are prominent features of the Shinarump section and form a notable interruption in the otherwise smooth profiles of the clays. In the most southwesterly section a 4-foot bed of black clay occurs 23 feet above the sandstone last described and is succeeded by green clay. In the middle section this black clay is 10 feet thick and contains lenses of chert. It is here succeeded by a bed of hard sandstone 2 feet thick, which causes a notable interruption in the otherwise smoothly domed profiles of the formation. This black clay is missing in the section on the northeast side of the Paria.

Besides these variations in the stratigraphy of the Shinarump clays it is also apparent that the colored bands, which appear so uniform in particular sections, are not persistent; but that in the same stratigraphic horizon the colors are to a considerable extent interchangeable.

Throughout the clays of the Shinarump there are numerous irregularly nodular concretions consisting almost wholly of carbonate of lime and magnesia. These have diameters ranging up to about 2 inches, but most of them measure less than an inch across.

On top of the Shinarump clays lies the massive, red Vermilion Cliff sandstone splendidly displayed in a vertical cliff on the northeast side of the Paria to a thickness of about 400 feet. The change from the clays to the sandstone is abrupt, and there is little or no evidence of the transitional gradation which Dutton has observed at this contact in other parts of the Plateau province. * * *

One of the most striking properties of the Shinarump clay is its behavior in water. Samples of the clay taken in the field are usually moist and the amount of water which may be driven off at 105° C. is very considerable. But when a fragment of the clay is immersed in water it immediately swells enormously and breaks down rapidly into an incoherent flat cone. When this material is examined microscopically it appears to be composed almost wholly of a colloidal substance with a very small admixture of fine silt and some concretions of carbonate of lime and iron oxide. The swelling and slacking of the clay in water is probably due to the colloidal absorption of water. The mixture is in such a fine state of division that it passes freely through filter paper. This peculiar behavior of the Shinarump clay is in marked contrast to other sedimentary clays, such, for example, as the clay of the delta of the Colorado. * * * The clays of the Shinarump require only to be sprinkled with water to cause them to promptly disintegrate and flow freely with the water. It is this behavior with water that has led to schemes of extracting their gold content by hydraulic methods. With rocks of this kind the rate of erosion, other things being equal, must increase as some large function of the increase of rainfall. If we assume that in Quaternary or Pleistocene time the rainfall of the region was x times greater than at present the rate of denudation was doubtless x^n times greater where "n" is no small figure. At present the rainfall is slight and the result is that the clays have been superficially disintegrated to a depth of from 1 to 2 feet. The swollen clay of this surface layer dries out and becomes a loose fluffy pulp of extreme lightness, softness, and incoherence. At times of heavy rains, such as occur occasionally on the desert, this material is washed down to the river in enormous quantities. It was found by experiment that swiftly running water carries in suspension about 30 per cent of its weight of dry pulp.

A sample of the gray Shinarump clay from Lees Ferry was submitted to chemical analysis by Prof. W. C. Blasdale with the following result:

SiO_2	53.45
Al_2O_3	18.56
Fe_2O_3	7.89
CaO	1.87
MgO	1.66
H_2O at 105° C.	6.77
Ignition loss above 105° C.	7.26
	97.46

There are also small amounts of carbonates and sulphates soluble in water in the clay. In it most of the iron is present in the form of minute concretions of limonite, and the lime and magnesia are in the form of carbonates. If we deduct these together with the corresponding amounts of H_2O and CO_2 and reduce the balance to percentages we get the following results: SiO_2=71.6; Al_2O_3=24.9; H_2O=3.5.

From this it appears that the ratio of silica to alumina is nearly 3:1, which is far greater than should be the case if the clay, deducting the concretions above referred to, were composed wholly of kaolin. There is not sufficient quartz present to account for the excess of silica. The proportion of water present is also much too small for kaolin. It seems probable, therefore, that a considerable proportion of the flocculent colloidal substance seen under the microscope is in reality silicic acid, and that the presence of silica in this form may account for the peculiar behavior of the clay with water.

GOLD DEPOSITS.

DISSEMINATED DEPOSITS IN CONSOLIDATED SEDIMENTARY ROCKS.

CHARACTER OF THE SEDIMENTS.

Finely distributed gold is reported to occur in the sedimentary rocks over wide areas in the Plateau region in formations ranging from Permian to Jurassic and possibly in still younger rocks. Considerable money and time have been expended on this class of deposits, but there had been no known production. Nevertheless the occurrence is of much geologic interest.

The gold occurs in sediments ranging from moderately coarse sandstone to extremely fine clay. It is all very finely divided and, it is said, can not be collected by panning, a fire or amalgamation assay being necessary to determine the tenor of the rock.

An attempt to extract the gold on an industrial scale has been made at Paria, on Paria River, in Kane County, about 15 miles north of the Utah-Arizona boundary, and at Spencer Camp, on lower San Juan River.[1]

PARIA AREA.

At Paria the gold is contained in part in an extremely fine clay of rather unusual character, which it was once thought might be treated by hydraulic methods. In the fall of 1911 considerable machinery for this purpose was freighted to the camp from Marysvale. So far, however, no method of profitable treatment has been devised.

Lawson [2] discusses the gold deposits of the clay as follows:

The purpose of my examination of the sections at Paria was in part to determine the quantity of gold present. * * * The nearly horizontal attitude of the beds made it possible to sample the clays by vertical cuts on the face of the bare hill slopes. The cuts were made deep enough to get beneath the veneer of slacked pulp which covers the unweathered clay. A sample from of 25 to 30 pounds was taken every 10 feet measured vertically by leveling. The sampling was done on the assumption that whatever gold the clay might contain was all very fine, and practically uniformly disseminated in any given stratum. The lower part only of the formation was sampled, comprising from one-half to two-thirds its entire thickness. The samples, after careful crushing and quartering, were submitted to Mr. E. H. Simonds, of San Francisco, for assay. This he did with the utmost care, in quadruplicate for each sample.

The first series of 18 samples was taken from a trench 174 feet high on the southwest side of the Paria River. Of these one was found to contain 10 cents per ton, nine 5 cents per ton, two 2½ cents per ton, four contained a trace, and one contained none. These results were checked by taking an aggregate made up of equal weights of every one of the 18 samples. The assay of this aggregate sample was 5 cents per ton. It is worth noting that the sample which yielded 10 cents per ton was taken from the 15-foot bed of sandstone described as occurring in this section.

The second series of 22 samples was taken from a trench 210 feet high on the northeast side of Paria. Of these, one yielded 12½ cents per ton, two 7½ cents, eight 5 cents, five 2½ cents, five a trace, and one none. The average of the entire cut is about 4 cents per ton.

The third series of samples was taken from a trench 240 feet high, beginning at the top of the Shinarump sandstone on the southwest margin of the formation. Of these one yielded 7½ cents per ton, five yielded 5 cents, one 2½ cents, sixteen a trace, and one none. Confirming these results, an aggregate of equal amounts of 13 samples from the first series of 18 yielded to assay by Mr. W. S. Morley 4 cents in gold per ton. A similar aggregate of 16 samples from the second series yielded Mr. Morley 2 cents per ton, and an aggregate of 20 samples from the third series yielded also 2 cents per ton. Comparable results are obtained by amalgamation assays on large samples, using chemically pure mercury.

To those unfamiliar with the hydraulic method of mining, the gold content of the Shinarump clays may appear to be so small as to be insignificant and unworthy of attention from a practical point of view. But under the most favorable conditions gravel containing 5 cents per yard, or 2½ cents per ton, may be worked at a profit. The peculiar way in which the Shinarump clay slacks and runs with water suggests that it may be no less susceptible of hydraulicking than banks of gravel. This suggestion, coupled with an exaggerated notion of the amount of gold contained in the clays, has led to various attempts to exploit them for gold. The ground has been staked out in hundreds of placer claims and these have been offered for sale at large figures. The value of the ground is, however, very problematical. If a method of successful hydraulicking and recovery of the gold be developed, it will only be after a long period of experimentation, at large expense, at a few favored localities where a vast yardage of the clays is free from overburden and where abundant water may be had cheaply. No large expenditure for the acquisition of territory would be justified until the method of winning the gold has been demonstrated.

At present, the occurrence is interesting from a geological rather than a practical point of view. We may safely assume, on the basis of the sampling at Paria, that the Shinarump clay there contains on the average 5 cents per cubic yard. The same formation appears to be similarly auriferous at Lees Ferry and at San Juan, and it is probable from the extreme uniformity in the physical characteristics of the formation wherever it has been observed, that it is similarly auriferous throughout its extent. * * *

The gold is not confined to the Shinarump clays in the Plateau province. A cut 140 feet high was made in the underlying Permian shales and 14 samples secured for

[1] Gregory, H. E., Geology of the Navajo country: U. S. Geol. Survey Prof. Paper 93, p. 40, 1917.

[2] Lawson, A. C., op. cit.

assay. Of these, two yielded 10 cents in gold to the ton, five yielded 5 cents, six a trace, and one none. An aggregate of equal parts of these 14 samples yielded to an amalgamation assay 4 cents per ton. This result is probably representative of the gold content of the entire thickness of the Permian, since the conditions of sedimentation appear to have been very uniform throughout. The Permian beds do not, however, slack in water, and there is no prospect of their being susceptible of hydraulic mining. They are, however, quite as interesting as the Shinarump as an instance of the occurrence of gold in fine-grained sedimentary rocks.

SAN JUAN RIVER REGION.

Gold was first reported from San Juan River by an Indian trader named Williams in the fall of 1892. Tales of fabulously rich deposits, both in river placers and in sandstones adjacent to the river, spread through the West, and several hundred men "stampeded" to the region in midwinter (1892–93) and suffered great hardships. The river and its tributaries were staked for many miles. After fighting and bloodshed it was found that the gold was too fine to be worked on a small scale, and in a few months the region was practically abandoned.

The possibility of working the sandstone deposits has been investigated several times since. As late as 1910 machinery was taken into the region to crush and treat the rock but was never operated. The sandstone is said to contain 20 to 40 cents, or even more, per ton, in gold. The writer has not visited the district and has no reliable data pertaining to the gold content of the sandstones. It may be recalled, however, that apparently reliable reports stated that the deposits at Paria contained from 30 to 65 cents per yard in gold, and considerable money was spent on this assumption, whereas Lawson found that the average for those deposits is about 5 to 10 cents per cubic yard. It is possible that a more careful sampling will show a much lower content for the sandstones of San Juan River region than is commonly reported.

OTHER DEPOSITS.

The Triassic sandstones in the vicinity of the Henry Mountains are said to carry gold, assay values exceeding $1 per ton being reported. However, anyone considering working these sandstones should remember the Paria experience, and make careful investigation before attempting to treat them. Assays of sandstone from the La Sal Mountain region show gold and silver present. Ash from the Pleasant Valley coal is said to have yielded 60 to 80 cents per ton in gold.[1]

It is evident, as pointed out by Lawson, that the gold is widely distributed, but thus far it has not been found possible to extract it profitably. The widespread occurrence of the gold is of interest, however, as indicating that the sediments were derived from a rather highly mineralized area, and further, as furnishing a possible source for the placer gold of Colorado, San Juan, Green, and Grand rivers.

PLACER DEPOSITS.

GENERAL FEATURES.

Placer gold has been known for a number of years in the rivers of eastern Utah, including the Colorado and its main tributaries, Grand, Green, and San Juan rivers. The deposits have been worked sporadically and numerous devices have been tried for saving the very fine gold.

The richer gravels have been worked in a small way, some probably at a profit, but attempts to operate on a large scale have not met with success. The total production has been only a few thousand dollars, of which Colorado and Green River deposits have furnished the greater part.

The gold-bearing gravels are found at intervals from Wyoming to Arizona. They are most extensive, however, on Colorado River, between the mouth of Fremont (Dirty Devil) River and the southern boundary of the State, on Green River, above the mouth of the Duchesne, and on San Juan River near Bluff. Few of the river placers were visited by the writer, and little concerning them is to be found in the literature.

COLORADO RIVER.

DEVELOPMENT.

The most active operations on Colorado River have been carried on from about the mouth of Crescent Creek southward to a few miles below the mouth of San Juan River. Attempts at dredging and other placer operations were carried on farther south. The region has little rainfall and the tributary

[1] Jenney, W. P., The chemistry of ore deposits: Am. Inst. Min. Eng. Trans., vol. 33, p. 461, 1902.

streams normally carry little water, and many of them are dry for a large part of the year, preventing large hydraulic or sluicing operations with water from a source above the river. Pumping from Colorado River for sluicing is expensive. A water wheel was tried at the Good Hope Bar and was later set up at the Gold Coin placer, but was not notably successful. Dredges were used a short distance above the mouth of Pine Alcove Creek and farther south toward Lees Ferry, but neither was successful. Moreover, the very fine division and flaky character of the gold make it hard to save, and the percentage recovered by the methods so far employed is said to be very low. In view of these difficulties and the remoteness of the region, and the consequent high cost of supplies, it is not surprising that the efforts to work the placers have not met with marked success.

OCCURRENCE.

Gold is present in the river bed, in bars a few feet above the river, and in benches many feet higher. At the Gold Coin placer, according to Frank Bennett, the upper bench is 197 feet and the lower bench 65 feet above low-water mark. Other benches, said to be gold bearing, are estimated to be 1,000 feet above the river. These benches are remnants of old canyon bottoms in which lower channels have been progressively cut. The bench gravels examined are rather fine, few of the pebbles measuring more than 6 inches, and probably 50 per cent being less than 1 inch.

On some of the river bars coarser material was present and the relative proportion of coarse material was somewhat greater than on the benches. The fine material consists mainly of quartz sand but contains a large amount of heavy sands. The heavy sand consists mostly of magnetite, which can be readily removed by an ordinary hand magnet. A considerable portion of the remainder, consisting largely of hematite and ilmenite, can be removed with an electromagnet. The remainder is principally garnet, a black mineral that is probably chromite, zircon, and small amounts of rutile. Pebbles of hematite, the largest an inch in diameter, were noted, especially on the Gold Coin claim.

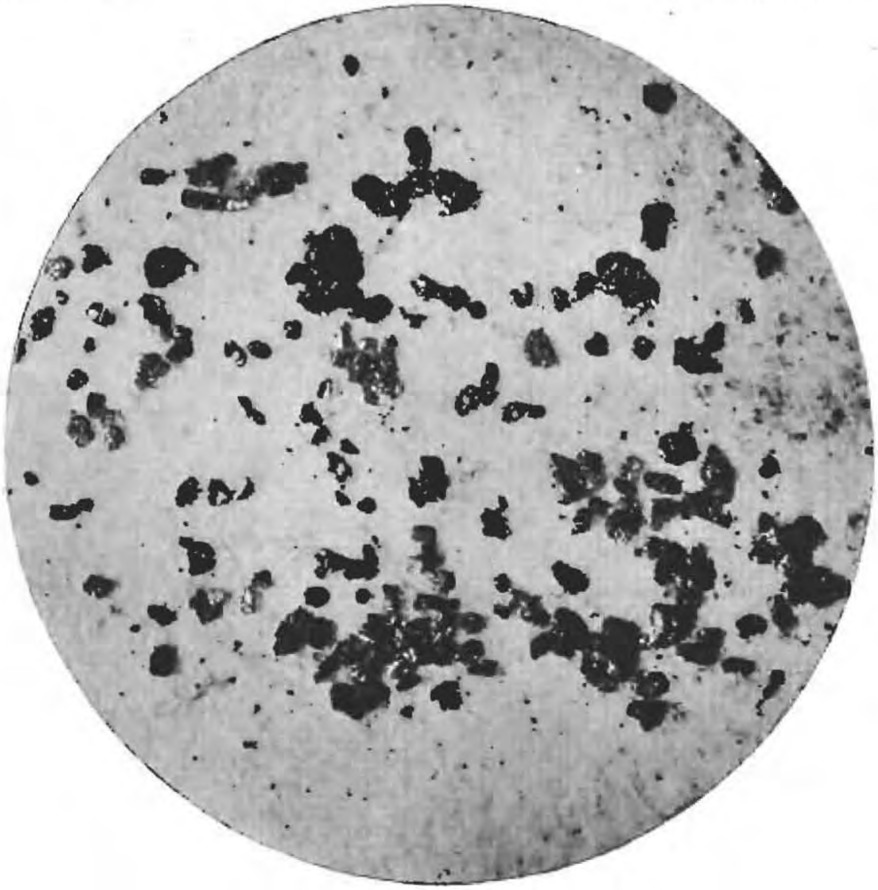
Many of the mineral grains composing the heavy sands are well rounded. Others, notably those of zircon and chromite, show nearly perfect crystal outlines. The heavy minerals are abundant in the gravels. Mr. Bennett states that the gravels of the Gold Coin placer contain as high as 6 per cent of "black sand," and other deposits probably contain about the same proportion.

The gold is in small flakes; the largest seen (in a sample panned from the Gold Coin placer) was 0.36 millimeter long and 0.26 millimeter broad. The average dimensions, however, are much less, the greatest diameter not greatly exceeding 0.10 millimeter. Flakes with a diameter of 0.05 millimeter are not uncommon. (See Pl. LI.)

Most of the gold from the Gold Coin placer is very clean and has the color of very pure gold. Some flakes, however, are yellowish green and are evidently not so pure. The gold is about 0.960 fine, but it is said to vary somewhat on different bars. The records of output from several bars show about 12 parts of gold to 1 part of silver. Three small colors of a gray metallic material, found in a pan from the Gold Coin placer, show the same rounding and pitting as the gold colors, and are believed to be platinum, which is known to be present in the deposits.

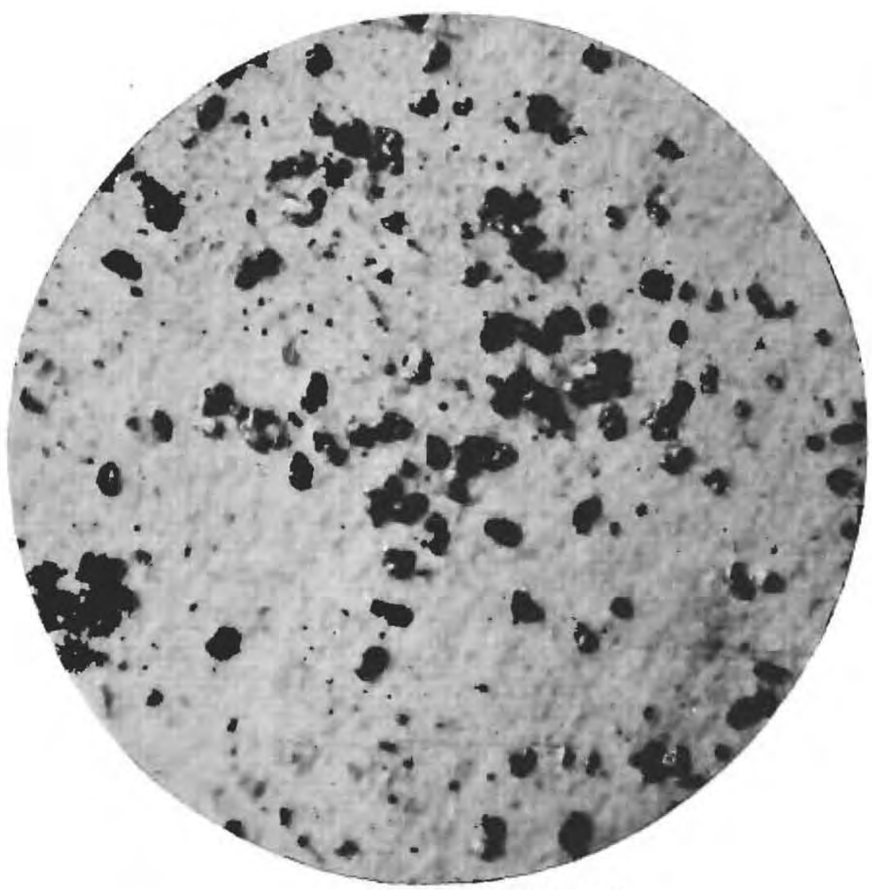
The gold content of the gravels is said to be rather uniformly distributed vertically instead of being concentrated on bedrock. The richest ground is said to contain considerable clayey material. The gold gravels are commonly covered by sand, in places several feet thick, that has been derived from the adjacent cliffs. Gravels at the upstream end of bars are said to contain more gold than those lower down; and the high benches are said to be commonly richer than the lower ones; but there are exceptions to both these rules.

The gold content of the gravels, of course, varies from place to place and to obtain an average would require very extensive sampling. Some of the results of operations are available, but it is reasonable to suppose that only the richer gravels were treated. Mr. Bennett states that about 1,000 yards of gravel from the upper bar of the Gold Coin claim yielded gold to the value of $730, or about 73 cents per yard. Gravels from a bar near the mouth of Red Creek are said to have yielded from 70 cents to more than $1 per yard. The "black-sands" are said to contain considerable gold that is not recovered.



A. PLACER GOLD OF COLORADO RIVER.

Enlarged 25 diameters.



B. PLACER GOLD OF GREEN RIVER.

Enlarged 25 diameters.

Very few data are available as to the platinum content of the gravels. A sample of "black sand" examined by D. T. Day and R. H. Richards[1] yielded 6.36 ounces gold and 0.15 ounce platinum per ton, and some high-grade gold concentrates are said to have assayed 1 part of platinum to 9 parts of gold.

Bert Seaboldt has kindly furnished estimates made by several men who have examined the gravel bars along the river. These estimates are based mainly on the results of panning and show a variation from 25 cents per cubic yard to double or triple that amount. The writer has heard other estimates as low as 5 cents per yard for the general run of the river sands. It is probably needless to say that great caution and skill are required in estimating the gold content of the gravels, and one accustomed to coarse gold is likely to be misled by the very fine and "flaky" gold of Colorado River.

SAN JUAN RIVER.

The placer deposits of San Juan River were not examined by the writer but have been described by Gregory,[2] who states that reports of rich deposits of gold in gravel bars and terraces of the San Juan, below the mouth of Montezuma Creek, caused the "Bluff excitement" of 1892, when 1,200 people rushed to the river and went away empty handed.

Several plants have been installed along the river, notably that of the Oregon Gold Mining Co., near the mouth of Montezuma Creek; at Zana Camp, 3 miles below the mouth of Nakai Canyon and about 20 miles above the junction of the San Juan and the Colorado; at Spencer Camp, in the Great Bend in the San Juan 6 miles below Zana Camp; and 4 miles below Nakai Canyon. Minor operations have been carried on at other localities.

The output from these operations has been small, and the larger undertakings, at least, have been failures. Gregory says: "That gold is widely distributed in the San Juan Valley is indicated by the fact that nearly every pan from the bars shows a color." The metal, however, is in excessively fine flakes. The cost of transportation is too great to justify operations without a yield larger than has been reported.

[1] U. S. Geol. Survey Bull. 285, p. 150, 1905.

[2] Gregory, H. E., Geology of the Navajo country: U. S. Geol. Survey Prof. Paper 93, p. 139, 1917.

GREEN RIVER.

Gold has been found and some prospecting done on Green River at numerous points from the Wyoming line southward. Gravels in Browns Park are said to contain gold, and some prospecting has been done, though there has been little production. Near Jensen attempts have been made to recover the gold by both dredging and sluicing, but neither method has been very successful in recovering the fine gold. Considerable prospecting has been done in the vicinity of Jensen, where large bodies of gravel are reported to contain gold in small amount. According to Newton Stewart, of Jensen, the gravels capping the mesas bordering Green River in that vicinity also contain gold in small amount.

At the Horseshoe Bend of Green River, about 15 miles a little west of south from Vernal, considerable placer mining has been done. This was the only locality where operations were being carried on at the time of the writer's visit, and circumstances permitted only a very hasty examination.

The gravels are on the inner side of the great oxbow curve made by the river. Where they occur, near the "top" of the bow, the river is cutting against its outer bank and has gradually receded from its inner bank. The gold-bearing gravels, which rise several feet above high-water mark, have been prospected along the river front for upward of a mile and are said to extend a quarter of a mile back from the river, though sufficient prospecting has not been done to outline their areas.

The pay gravel is said to rest upon clay, which is underlain by the decomposed sandstone of the region. The deposits are covered by sand that has drifted over them, in places to a thickness of 5 feet or more. The gravel contains many pebbles 2 to 4 inches in diameter or even larger but few boulders that exceed a foot in diameter. The gold is reported to be rather uniformly distributed vertically; at least it shows no marked tendency to concentrate at the base. There are evidently rich streaks horizontally and the same is probably true vertically.

The mineralogy of the fine material is similar to that of Colorado River. Magnetite is abundant, as are also garnet, hematite, ilmenite, chromite, and zircon. The gold is almost

identical in appearance with that of Colorado River in color, size, and shape, except that the sample examined contained fewer of the greenish-yellow "colors." Two flakes of a gray metallic mineral collected in a pan are believed to be platinum.

The gravels vary in gold content from place to place, and it is difficult to determine their average tenor. Some of the gravel worked is said to have yielded $1 per yard. In these operations, however, the better ground was selected, and it is safe to say that in any large operations the average would be very much lower.

The only water supply is Green River and in working the ground it is necessary to elevate both the gravel and the water.

As in other places in eastern Utah difficulty has been experienced in recovering the fine gold. In the fall of 1913 the Fine Gold Placer Mining Co. had nearly completed a plant designed especially for recovering the fine gold, but to the present time (1917) it has made no important production.

GRAND RIVER.

A small amount of placer gold has been recovered from the bars of Grand River. The writer did not see these deposits, but they are said to be similar to those of Green and Colorado rivers.

SOURCE OF THE GOLD.

The source of the gold in the placers has never been definitely ascertained and has been much disputed.

It is, of course, recognized that the gold-bearing veins of the La Sal, Abajo, Henry, and possibly Uinta mountains may have and probably did furnish a portion of the gold, though the gold of the Henry Mountains at least is said to differ considerably from the river gold. Moreover, so far as known at present, the veins in these mountains do not seem adequate to account for the gold along the rivers.

It seems to be the prevailing opinion among men who have worked the river deposits that the gold in the sedimentary rocks has been concentrated to form the auriferous gravels of the rivers.

Schrader[1] has described very similar deposits from Wind and Big Horn rivers, Wyo., and considers their most probable source to be the lodes in the pre-Cambrian rocks. Green River heads in essentially the same region, and it is entirely probable that at least part of its gold has been derived from a similar source and has been concentrated by repeated reworkings. In like manner it is possible that the gold of the San Juan placers was derived from the lode deposits near the headwaters of that stream.

[1] Schrader, F. C., Gold placers of Wind and Big Horn rivers, Wyo.: U. S. Geol. Survey Bull. 580, pp. 127-145, 1914.

APPENDIX.

CARBONIFEROUS AND TRIASSIC FAUNAS.

By George H. Girty.

DISCRIMINATION OF FAUNAS.

The plates of Carboniferous and Triassic fossils that accompany this report were made up at the request of Mr. Butler with the purpose of aiding the geologist to discriminate and identify the rock groups that he was called on to investigate. The performance of this task in a way that would accomplish the desired object was less simple than it may appear. The first requirement of any form selected for illustration as characterizing a given geologic age was that it must be closely restricted to the rocks of that age. Any species that ranges beyond the limits of a formation was ineligible in proportion to this transgression. It was also necessary that the species selected should be of common occurrence, for obviously any type that was rarely found, though ever so sharply restricted in geologic range, would be of little use for the purpose required. Again, it was necessary that the species selected should be easily recognized, for though many types that are more or less restricted to and characteristic of definite horizons are readily differentiated by the trained eye, it is for the layman and not the professional paleontologist that these plates are primarily intended, and if the layman can not readily detect the difference between the forms they might as well, for him, be the same form. Lastly, it was necessary that the species selected should be species that occur in Utah. This requirement was in one way helpful, because species that in one region are restricted in range and are characteristic of a definite horizon may in another pass through several horizons and not be characteristic of any. In another way, however, this requirement introduced an element of hazard, for if the species ranges through several faunas in another area its apparent restriction to one horizon in Utah was probably apparent only and the appearance was due to insufficient evidence.

Now there are really very few species that fulfill all these requirements, and the user of these plates will probably find them serviceable in proportion to the accuracy of his observation and the soundness of his judgment. He is likely to find similar forms, though rarely the same forms, at more than one of the horizons here differentiated. He must not expect to find in one spot all the forms figured as characterizing a horizon, though he may find them, and, on the other hand, he must rest his judgment less on the presence of any one of the forms and more on the association of a number of them.

Proceeding along broad lines, I have distinguished four Carboniferous and one Triassic fauna in Utah, and these are represented, though of course in a very partial way, on the six accompanying plates. Each of the faunas will doubtless be subdivided into several stages when it has been studied carefully in connection with more detailed stratigraphic information than is now available.

LOWER MISSISSIPPIAN FAUNA.

The lower Mississippian fauna corresponds to the Madison limestone fauna of Montana, Wyoming, and other States. The term Waverly has been applied to it in many of the reports on the geology of Utah because of its resemblance to the fauna of the Waverly group of Ohio. The Madison horizon is commonly very fossiliferous and can often be identified by that fact alone. *Spirifer centronatus* is abundant at this horizon, also the very finely striated *Chonetes loganensis*. Species of *Chonetes* and *Spirifer* similar to these occur in the Pennsylvanian. *Leptaena analoga* appears to be absolutely diagnostic of the Madison fauna in Utah wherever it is found, but it is rather rare. Large, loosely coiled gastropods of the *Euomphalus* and *Straparollus* group are an important feature of the Madison fauna. Species resembling the Madison species do indeed occur at other horizons, but at these they are far less abundant.

UPPER MISSISSIPPIAN FAUNA.

The two plates of upper Mississippian fossils constitute a somewhat new and not unimportant contribution to the paleontology of Utah. The upper Mississippian is lacking over vast areas in the West, owing apparently to pre-Pennsylvanian erosion, so that Pennsylvanian rocks rest directly on limestones of Madison age, and it was not until rather recently that I had the necessary faunal and stratigraphic information to establish the presence of rocks of upper Mississippian age in Utah. Most of the species shown on the plates have already been recognized in Utah, but their horizon as upper Mississippian has not been recognized, or at least has not been plainly indicated. The assemblage of species as shown here is more or less provisional; some of the types may not belong in the upper Mississippian at all and others may belong in different subfaunas. Upper Mississippian rocks occur also in Idaho, where, in fact, my best collections have been obtained. The fauna deserves full and careful treatment. This horizon is especially characterized by its corals. Large zaphrentoid corals like those figured, possessing numerous rays or septa, are in many places very abundant and are more or less characteristic, though smaller species similar to them are found at almost all horizons in the Paleozoic. Large colonial types are also abundant, especially in Idaho. They belong chiefly to the genus *Lithostrotion*. A large *Productus* of the type of *P. giganteus* and a large *Spirifer* of the type of *S. striatus* are likewise significant. In general, the upper Mississippian fauna of this region resembles the fauna of the Mountain limestone of Great Britain, the Ural Mountains, and eastern Asia more than it does the higher Mississippian of the upper Mississippi Valley region, but in a measure it combines the two facies.

PENNSYLVANIAN FAUNA.

The Pennsylvanian faunas of Utah are perhaps less known than those of any other horizon, for the rocks of Pennsylvanian age do not contain many fossils and are not adapted lithologically to preserve them well. The fauna, so far as it is known, seems to come mostly from the lower part of the Pennsylvanian of Utah, and it resembles the lower faunas (post-Pottsville, however) of the Pennsylvanian of the Mississippi and Ohio valleys.

PERMIAN FAUNA.

The Permian fauna of Utah is a very distinct and easily recognized unit. It is the *Spiriferina pulchra* fauna that at one time spread over Idaho, Wyoming, Utah, and Nevada. Because it is pronouncedly unlike the Carboniferous faunas that preceded it and because it includes a few types like *Aulosteges* (which, so far as known, is restricted to rocks of Permian age) the *Spiriferina pulchra* fauna is classed as Permian. It does not, however, agree closely with the typical Permian fauna of Russia, and it is strikingly different from the other Permian faunas of North America such as the Guadalupian fauna or the Kansas and Texas Permian. Indeed, it is doubtful whether as much as 10 per cent of its species can be found in the central and eastern parts of the continent, and even that small proportion belongs to such baffling types as *Composita*, in which few sharp specific lines can be drawn. As presented on Plate LVI, the *Spiriferina pulchra* fauna has little that is new and valuable to the professional paleontologist, except perhaps that it brings together somewhat more definitely than before certain species, already known, into a single well-defined fauna.

LOWER TRIASSIC FAUNA.

The Lower Triassic of Utah as now known comprises the beds called Permo-Carboniferous by the geologists of the King Survey and by others. In the Park City district "the Permo-Carboniferous" was discriminated into three formations, the Woodside, Thaynes, and Ankareh, but these formations have not as yet been traced across the State. They have, however, been traced into southeastern Idaho, where they were found to embrace the *Meekoceras* beds, the typical Lower Triassic of North America. The *Meekoceras* beds are regarded as occurring in the Thaynes limestone. In addition to *Meekoceras* and other types of Ammonites the Lower Triassic has a large and varied fauna comprising pelecypods and gastropods, besides some brachiopods and Bryozoa, unfortunately as yet almost completely undescribed. The typical ammonite fauna is not known in the lower part of the "Permo-Carboniferous" (Woodside), but the molluscan

species found there ally this part of the section with that above. Because of this alliance, because the formation next below appears to be Permian (the final epoch of the Paleozoic), and because a most profound and abrupt faunal change occurs between the Permian fauna and the Woodside (all the abundant and characteristic Paleozoic types of brachiopods, such as *Productus*, *Chonetes*, *Derbya*, *Composita*, *Spirifer*, and the rest, becoming extinct at that fatal line), the Woodside is confidently grouped with the overlying beds, with which, indeed, it lithologically belongs. If the *Meekoceras* fauna of the Thaynes is Triassic, the Woodside also is Triassic.

The Lower Triassic fauna originally extended the entire length of the State from Idaho to Arizona and probably westward into California. In Walcott's Kanab Canyon section it forms the beds which he calls Permian, his Permian fauna containing one or two species of *Meekoceras* as well as many pelecypods that occur also in the "Permo-Carboniferous" of the Wasatch Range. The exact equivalence with the Lower Triassic of northern Utah can not be predicated, but from such facts as are now available it seems probable that all of the Kanab Canyon "Permian" is Triassic and that the underlying Carboniferous limestone (Kaibab) is Permian.

DESCRIPTION OF SPECIES.

Productus brazerianus Girty, n. sp.

Pl. LIII, figs. 1, 1a, 2, 2a.

Shell large, subquadrate. Probably the width always exceeds the length, but in some specimens it exceeds it much more than in others. The hinge line is as wide as or slightly wider than the shell in front and the cardinal angles are nearly right angles. The anterior outline is broadly curved and the lateral outlines nearly straight above. The convexity of the ventral valve is low, greatest toward the margins. The beak is small and not very prominent. The ears are rather large, undefined, and arched, and are separated from the vault of the shell by a broad depression. The dorsal valve is shaped much like the ventral (as viewed from the inside) save that the convexity is lower and more regular and the beak smaller and less prominent.

The surface is marked by fine, subequal, radiating costae which increase by bifurcation and are somewhat wider than the striae between them. They are more or less wavy and irregular. There are also fine, concentric, crenulating striae and concentric wrinkles, which as a rule are fine, irregular, and faint. I have not been able to determine definitely whether spines are present in this form; presumably some were developed but probably they were neither large nor numerous.

This type is very abundant in the upper Mississippian (Brazer limestone) at certain localities, but at others it can not be found at all. The shells are apt to be so packed one upon the other that it is difficult to obtain perfect specimens. In general *Productus brazerianus* suggests *P. cora* and other species related to it, but from these forms it is clearly distinguished by its broad shape, its low convexity, its small beak, and by its lack of large spines on the body of the shell, and of strong wrinkles on the ears. More immediately, it is of the family of *P. giganteus* and may be identical with some of the varieties of that species. *P. giganteus*, however, is in an unsatisfactory state, because of the large number of forms that have been referred to it. For this reason and because I have no specimens whatever for comparison, I have deemed it better to describe as new the American form and leave for future determination its relation to the European one. What may probably be regarded as typical *P. giganteus* is, I judge, distinct from my shell by reason of its greater size, high convexity, much extended auricles, longitudinal folds, cardinal spines, and other characters. Young specimens perhaps show some of these differences less clearly.

Productus hemisphericus, which Davidson considers only a more or less doubtful variety of *P. giganteus*, resembles *P. brazerianus* more than *P. giganteus* itself. It shows, however, some of the same differences, such as the row of spines along the cardinal line and the extended ears (not, however, in all specimens [1]). One of Davidson's specimens of *P. striatus* also suggests *P. brazerianus*, but of course the short-hinged spatulate typical variety resembles it only remotely. Even *P. cora*, as identified by Davidson, is not without suggestions of *P. brazerianus;* not only is his form a different species from true *P. cora*, however, but as com-

[1] Davidson, Thomas, British fossil Brachiopoda, vol. 2, pl. 40, fig. 9, Paleont. Soc., 1858-1863.

pared with *P. brazerianus* it is more highly vaulted, has a larger and more prominent umbo, and has much stronger concentric wrinkles.

Although *P. brazerianus* is apparently distinct from typical *P. giganteus*, most citations of *P. giganteus* in American literature probably belong to it. It is also probable that the form identified by Meek in Montana as *P. latissimus* belongs to *P. brazerianus*, but this suggestion is made only on the hypothesis that Meek's specimen was imperfect.

In configuration *P. brazerianus* closely resembles *P. magnus* of the Mississippi Valley region. *P. magnus*, however, has its surface sprinkled with numerous small spines and has costae that are not only coarser but that tend to become obsolete toward the front. *P. siebenthali*, a manuscript species from the Hindsville member of the Batesville sandstone of Arkansas, is also an allied form. The dorsal valve of *P. siebenthali* has numerous, more or less strong, fine, concentric wrinkles, and the ventral valve has a row of spines along the hinge line and does not show the broadly flattened shape over the visceral region which is rather characteristic of *P. brazerianus*. The costae are likewise much finer. The differences in the number and distribution of the spines can not be pressed, though I have been quite unsuccessful in finding definite evidence of spines in *P. brazerianus*, especially along the hinge line and on the ears, where they would be apt to be larger and more numerous than on the rest of the surface.

Aulosteges hispidus Girty, n. sp.

Pl. LVI, figs. 8, 8a, 8b.

Shell rather large, ovate, expanding from an almost pointed posterior to a broadly rounded anterior end, the outline but little interrupted by the projection of the small depressed ears. The largest specimens observed are about 40 millimeters long. The width is variable but always distinctly less than the length. The convexity of the ventral valve is moderate, rather high transversely, and more shallow lengthwise. The sides and front are apt to descend strongly, but the slope backward to the umbo is apt to be gradual. The auricles are small and indistinct. The cardinal area is low; it lies about in the plane of the shell edges.

The dorsal valve is nearly flat, of an ovate shape with a small terminal beak.

The surface of the ventral valve is marked by very fine, wavy, radial lirae, as in some varieties of *Productus cora*. There are also numerous rather stout spines which appear to be differently arranged in different specimens. Commonly there appears to be a rather broad spinose belt passing around the shell well toward the front, in which the spines are large and closely set. In several specimens the shell in front of this band is almost without spines and is marked only by the fine, sharp, wavy lirae. In some specimens again the surface back of the spinose band appears to be almost without spines, or to have the spines smaller and less numerous than on the band itself. Such appears to be the character of this part of the surface in the type specimen. The spines are really rather numerous, but they are smaller than those on the spinose band and are broken off so close to the surface that they are represented only by small perforations in the shell and are therefore less conspicuous than those of the band, which stand out prominently.

Aulosteges hispidus unquestionably belongs to the group of *Aulosteges*. This relationship is indeed strongly suggested by the shape and surface characters alone and is proved by the area of one specimen, which I uncovered with some difficulty. The area is small, being only about 3 millimeters high in a specimen at least 25 millimeters long. It is marked by transverse grooves and has a narrow pseudodeltidium. The pseudodeltidium itself, however, appears in the specimen to be broken or cut away, leaving a small open slit.

Of the American species referred to this genus *A. hispidus* resembles *A. guadaloupensis* in shape but differs from it widely in surface character. It agrees more nearly with *A. medlicottianus* var. *americanus* in sculpture but differs from it in configuration. Even the sculpture, though similar in general plan, differs notably in detail.

A. hispidus is one of the rarer species of the *Spiriferina pulchra* fauna, but it is important in determining the geologic age of that formation, all the species of *Aulosteges* being, I believe, of Permian age.

Spirifer pseudocameratus Girty, n. sp.

Pl. LVI, figs. 10–15.

Shell rather large, distinctly wider than high but less transverse than many species of the

genus. The greatest width is found at the hinge line, the cardinal angles being acute in shells that are proportionally wide but more nearly rectangular in shells that are proportionally high.

The ventral valve is rather convex, especially in the umbonal region, and the rather small beak is strongly incurved. The area appears to be high in some specimens but only moderate in others; it is somewhat oblique to the plane of the valves but is more or less strongly recurved toward the perpendicular. The sinus is not deep but is fairly well defined. It is occupied by two small costae that unite toward the beak and gradually enlarge toward the front where they are of about the same size as the other plications. The costae that border the sinus, one on each side, also give off by division one and sometimes two costae on the sides or in the bottom of the sinus. The costae on the sides of the shell are strongly fasciculate in groups of three, and these may be subequal, or one may be large and two small. Of these fascicles there are three or four on each side of the beak; four or five other costae, either in pairs or singly, are developed beyond, toward the cardinal angles.

The dorsal valve is moderately convex. The fold is low but well defined. It is divided into two lobes by a more or less deep median groove. Each lobe bears two or three costae, and the lobes so closely resemble the fascicles on the sides that in some specimens it is not at first apparent that there is any fold at all. The lateral costae, like those of the ventral valve, are strongly fasciculate near the fold and grade laterally into a nonfasciculate arrangement.

The finer surface markings are not well shown. Probably like other species of the same kin, this one was covered with fine radial and concentric tracings, but at present only the striae of growth can be seen.

This species will immediately suggest the common Pennsylvanian type, usually known as *Spirifer cameratus*. More careful comparison, however, will show numerous differences. Though both species vary more or less, *S. pseudocameratus* is higher in proportion to its width, whereas *S. cameratus*, or, as I shall call it, *S. triplicatus*, is proportionally wider and more extended at the hinge line. *S. triplicatus* has rather finer costae and a more rapidly widening fold and sinus. Its fold and sinus are also more angular, the fold especially being high and pointed, whereas that of *S. pseudocameratus* is low and rounded. The fold of typical *pseudocameratus* is, moreover, rendered biplicate by a median groove; and though a median groove occurs on the fold of *S. triplicatus* also, it is shallow and merely blunts the crest of the ridge. *S. triplicatus* also has more numerous costae in the fold and sinus.

This is probably the same species that Meek identified as *Spirifer cameratus*, though Meek's specimens were obtained in Nevada instead of Utah. Meek noted several differences from typical *S. triplicatus*, in part the same differences because of which I consider *S. pseudocameratus* distinct from *S. triplicatus*. He apparently placed so much importance on the fact that his form, like *S. triplicatus*, had fasciculate costae that he did not give adequate weight to other differences of which he himself noted some, others perhaps not being shown by his specimens, which were evidently not very good. My own, too, are rather poor, but I have many of them.

Spirifer triplicatus Hall.

Pl. LIV, fig. 22.

By this name, used by Hall in 1852, I intend to designate the species currently known as *Spirifer cameratus* Morton. Morton's type specimens were obtained at Putnam Hill near Zanesville, Ohio; Hall's from a locality in northeastern Kansas. *S. triplicatus* is a common and well-known form that occurs in the coal measures of Missouri, Illinois, Kansas, and other States in the same region. Typical *S. cameratus* is from the Pottsville (Mercer limestone). It is common at Putnam Hill, and my collection contains a number of specimens. Broadly speaking all these early spirifers of the *triplicatus* group have the ribs less strongly fasciculate than typical *S. triplicatus*. This is true at least of my specimens of *S. cameratus* from Putnam Hill and they also differ more or less in having the fold and sinus rather low and rounded instead of high and angular. They seem to have a more quadrate or pentagonal outline than *S. triplicatus*, one which is higher in proportion to the width, less extended at the hinge, and fuller below it. These differences appear to be maintained perhaps only in a general way and to be not very great in degree, but in my judgment they warrant holding

S. cameratus as distinct from *S. triplicatus*, both on their own account and on account of the difference of geologic age with which they are correlated.

I propose therefore to recognize two species among this group of spirifers, for one of which *S. cameratus* is clearly the oldest name and for the other probably *S. triplicatus*. The only term that seems at present likely to conflict with *S. triplicatus* is *S. meusebachanus* Roemer, which has priority over *S. triplicatus* but not over *S. cameratus*. It is impossible at this writing to determine with certainty the relationship of the Texas form. It may prove to be distinct from both *S. triplicatus* and *S. cameratus*; if it belongs to either it belongs probably to *S. cameratus*. To distribute correctly the long synonymy of *S. cameratus* would be difficult. Most of the citations would doubtless fall to *S. triplicatus*. Another species that must be considered in this connection is *S. gorei* Mather, which is said to differ from *S. cameratus* (*S. triplicatus*) by lacking fasciculate ribs. Mather's statement is that the ribs of *S. gorei* are not fasciculate at all, whereas those of *S. cameratus* are only faintly fasciculate. The two forms may be distinct species, but their geologic age is about the same.

Composita mira Girty.

Pl. LVI, figs. 16, 16a.

1877. *Athyris roissyi* Meek, U. S. Geol. Expl. 40th Par. Final Rept., vol. 4, pt. 1, p. 82, pl. 9, figs. 3-3b. Carboniferous limestone: Ruby group; Wachoe Mountains; Mahogany Peak; Egan Range, Nev.

1899. *Athyris mira* Girty, Geology of the Yellowstone National Park: U. S. Geol. Survey Mon. 32, pt. 2, p. 570.

A large *Composita* occurs rather persistently in the *Spiriferina pulchra* fauna of Utah. It is characterized by its large size, its rotund shape, its narrow fold and sinus which though rather strong are developed chiefly toward the front, and by its surface markings, which consist of numerous rather strong, irregularly disposed, imbricating lamellae of growth. There is also a narrow variety of this form in the *Spiriferina pulchra* fauna. It is commonly much longer than wide, even the most rotund specimens being only slightly wider than long.

These specimens appear to agree remarkably well with the form to which, in 1899, I gave the name *Athyris mira*. The original specimens of *Athyris mira* were the original specimens of *Athyris roissyi* as identified by Meek. Meek's specimens came from Nevada, and they are distinguished by almost the same characters that I have mentioned for those from Utah. I called attention to the fact that *Athyris mira* possessed an open, triangular delthyrium, instead of the round pedicle opening depicted by Meek's figure, whose appearance I was inclined to ascribe to breakage. The conformation of Meek's specimen, however, may be no different from that which can often be observed in *Composita*. In ventral valves of that genus the triangular delthyrium was mostly closed by a deltidium, and the small round pedicle opening above the deltidium encroached on the umbo through resorption or wear by the pedicle. The deltidium is in fact rarely preserved, but owing to the curvature of the ventral beak that part of the shell is concealed by the other valve. When the dorsal valve is lost, however, or has the umbonal part broken, the ventral valve is apt to show a triangular aperture below, open because of the loss of the deltidium, and a circular aperture above occupying the apex of the umbo. Thus the condition observed in *Athyris mira* may not be as anomalous as I conceived it to be at the time.

As to the generic position of *Athyris mira*, the configuration appears to be that of *Composita* rather than of *Athyris* or *Cliothyridina*. In fact, Meek states that his specimens of *Athyris roissyi* pass by easy gradations into forms that are difficult to separate from *Composita subtilita* Hall. The really critical character in these shells, however, is the surface ornamentation. Meek's specimens have the surface marked by stronger and more numerous imbrications than is common in *Composita* but certainly not stronger and more numerous than is compatible with that genus. On the other hand, there is not the slightest evidence for believing that the imbrications of *A. mira* were ever prolonged into the spinose fimbriae of *Cliothyridina* or the lamellose frills of *Athyris*. Indeed, I strongly believe that they were not prolonged. I am satisfied that they were not prolonged in the Utah specimens, which I refer without hesitation to *Composita*. The main difference shown by the Utah specimens, when compared with Meek's description and figures, is that Meek represents the imbri-

cations as more regular though apparently not stronger than they are in my specimens.

Meek's figures of *Athyris roissyi* strikingly resemble his figures of *Athyris? persinuata* on the same plate, and apparently the two forms occur in association. *Athyris persinuata* seems to be rather smaller, rather more elongated, to have a stronger fold and sinus, and to lack the regular imbrications, those which it has occurring only toward the margin. It is probable that both forms actually belong to the genus *Composita*, and if the differences mentioned do not hold good *Composita mira* will become a synonym of *C. persinuata*. The shells from Utah agree better with *C. mira* than with *C. persinuata* for, though they vary considerably in other characters, none of them has the fold and sinus so remarkably developed as they appear to be in Meek's species.

Compositas of uncommonly large size seem to be somewhat characteristic of the late Carboniferous faunas of North America, a very robust type that much resembles this one occurring in the Permian of Kansas. The Kansas form is probably distinct from *C. mira*, however, by reason of its nearly smooth surface and its more ovate shape, which tends to be relatively longer and to have its greatest width farther toward the front of the shell. In the Utah specimens the greatest width is about midway, though the difference is not entirely constant.

Aviculipecten? deseret Girty, n. sp.

Pl. LVII, figs. 7-9a.

Shell small. Length slightly greater than width. Hinge line short, about one-half the width lower down or a little more. Beak nearly central on the cardinal line to which the axis of the shell is nearly perpendicular. Shape more or less symmetrical though one side is usually a little better developed than the other. The ventral and lateral outlines are regularly rounded. Above the middle the outlines contract somewhat, then become subparallel and nearly straight, so that the two ears are similar in size and shape, and the cardinal angles are angles of 90° or somewhat less. The convexity is moderate with a gradual descent to the ears, which are depressed but not defined either by a sulcus in the surface or a sinus in the outline.

The sculpture consists of numerous fine, regular, unequal radiating costae. The costae of the largest size number about 20. Between these occur three or more much smaller ribs, of which the median one or two are as a rule distinctly more prominent than the others. Even the primary costae are more or less perceptibly alternating, so that the ribs really belong to three and possibly four or more series. They are relatively high and thin, and the striae between them are broad and flat. Toward the sides the costae rapidly become finer and more equal, so that the ears are almost, if not quite, smooth in some specimens and in others covered with very fine, equal lirae. There are also very fine, regular, concentric lirae of about the same size as the finest radiating ones but more closely arranged, and with the costae they produce a finely cancellated surface. They do not seem to cross the larger ribs, or at least to make crenulations upon them.

This species seems normally to have a length of 16 millimeters, but many specimens are smaller.

The generic position of *Aviculipecten? deseret* is a matter of doubt. I have some reason to believe that the shell is equivalve, and in that case the generic position would not be with *Aviculipecten* nor even with the Pectinidae. None of the specimens observed has any trace of a byssal sinus, from which fact, from their sculpture, and from their convexity all must, on the assumption that they belong to the Pectinidæ, represent one valve only of the complete shell and that the left valve. Now, it would seem somewhat paradoxical to find in the same collection over 30 specimens of the left valve and no corresponding right valves nor even any shells of different character that could with any probability represent the right valve. Furthermore, as has already been mentioned, though most of the specimens are almost symmetrical bilaterally, some seem to be better developed on one side and others on the other. Finally, though the axis is in a general way about perpendicular to the cardinal line, it appears to be slightly curved in the umbonal region, pointing in some specimens toward one side and in other specimens toward the other. With this difference may be correlated a slight inequality in the proportional length of the parts of the hinge

line on either side of the umbo (the beak pointing to the longer side?) and also a slight inequality in the descent of the shell to the two ears. To determine this correlation of parts would require a larger series of complete specimens than is contained in my collection.

Aviculipecten? deseret is closely related to *Aviculipecten? superstrictus* White. It differs, however, in being only half as large, in being relatively shorter on the hinge line, and in being much less gibbous, with a correspondingly more gradual descent to the ears. *A. superstrictus* is more copiously supplied with the small intermediate lirae, which are, moreover, less strongly differentiated in size. The regular concentric lamellae are also lacking on *A. superstrictus* so far as observed, but the typical specimens are not so preserved that this character would be well shown, if originally present.

Myalina? platynotus (White).

Pl. LVII, figs. 16, 17.

1880. *Volsella (Modiolina) platynota* White, U. S. Geol. and Geog. Survey Terr., Contributions to invertebrate paleontology Nos. 2-8, p. 146, pl. 37, figs. 3a, 3b. Jurassic (?); Head of Lincoln Valley, southeastern Idaho.

1883. *Volsella (Modiolina) platynotus* White, U. S. Geol. and Geog. Survey Terr. Twelfth Ann. Rept., for 1878, pt. 1, p. 146, pl. 37, figs. 3a, 3b. Jurassic (?); Head of Lincoln Valley, southeastern Idaho.

This form is well distributed and abundant in the Lower Triassic of Utah and Idaho and appears to be characteristic of the horizon. It is largely confined to the Thaynes limestone and the specimens illustrated are from that formation. It is not certain that my specimens belong to the species described by White as *Volsella (Modiolina) platynota*, and my figures do not look at all like his because they are differently oriented, what he regards as the anterior side being in my figures represented as the hinge. As to the orientation of my specimens there can be little doubt, because the side which I regard as the hinge is straight and has a very distinct cardinal area or hinge plate, whereas the side that corresponds to the hinge of White's figure is curved and has a thin edge without any suggestion of cardinal structures. Of course, if the orientation of White's figure is correct, the two forms are widely different, not only in specific but in generic character.

I have referred my form to the genus *Myalina* because in shape and in what little is known of the structure it is more or less comparable with the Carboniferous Myalinas. I much doubt whether it is a true *Myalina*, however, and even if it is it represents a type distinctly different from the Myalinas of the Pennsylvanian and Permian of this country.

PLATES LII-LVII.

PLATE LII.

Zaphrentis stansburyi Hall.

FIGURE 1. Side view of an imperfect specimen, which has the edge of the calice and the lower extremity broken away.

After Meek, Paleontology, U. S. Geol. Expl. 40th Par. Final Rept., vol. 4, pt. 1, pl. 6, fig. 3, 1877. Hall's specimens came from Stansburys Island, Cloth Cap, and Flat Rock Point, in Great Salt Lake, and the original of Meek's figure, copied here, came from the same horizon in the Wasatch Range, Utah.

Zaphrentis? multilamella Hall?

FIGURE 2. A specimen broken longitudinally, showing imperfectly the internal structure. The fossula is on the right.

2a. A view of the calice of the same, with its margins broken away and its bottom filled with rock.

After Meek, Paleontology, U. S. Geol. Expl. 40th Par. Final Rept., vol. 4, pt. 1, pl. 6, figs. 4a and 4b, 1877. Hall's specimens came from Cloth Cap and Flat Rock, in Great Salt Lake, and the original of Meek's figures, copied here, came from Strongs Knob, in Great Salt Lake.

Cyathophyllum nevadense Meek.

FIGURE 3. Side view of a much-weathered specimen showing the edges of the septa and the dissepiments, and the calice, seen obliquely, partly filled by hard calcareous matter.

After Meek, Paleontology, U. S. Geol. Expl. 40th Par. Final Rept., vol. 4, pt. 1, pl. 6, fig. 3, 1877. The original specimen is from Boxelder Peak, Wasatch Range, Utah.

Zaphrentis excentrica Meek.

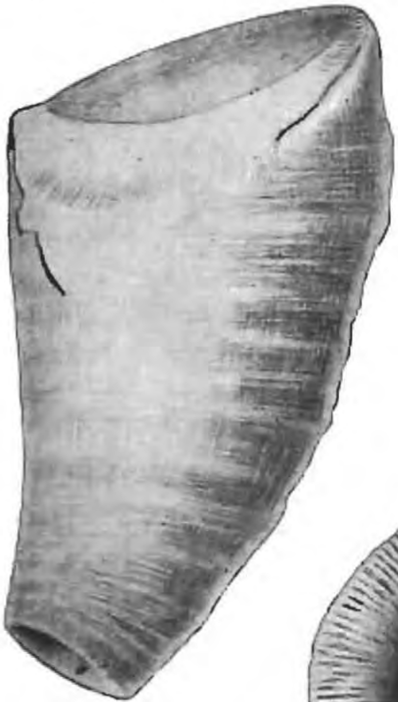
FIGURE 4. Side view of the type specimen.

After Meek, Paleontology, U. S. Geol. Expl. 40th Par. Final Rept., vol. 4, pt. 1, pl. 4, fig. 1c, 1877. The original specimen is from Boxelder Peak, Wasatch Range, Utah.

Lithostrotion whitneyi Meek.

FIGURE 5. A mass of limestone including several of the corallites.

After Meek, Paleontology, U. S. Geol. Expl. 40th Par. Final Rept., vol. 4, pt. 1, pl. 6, fig. 1, 1877. The original specimen is from Boxelder Peak, Wasatch Range, Utah.



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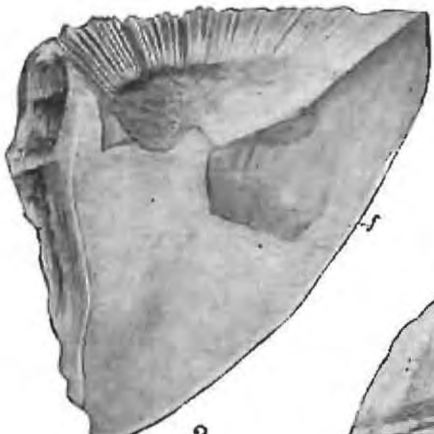

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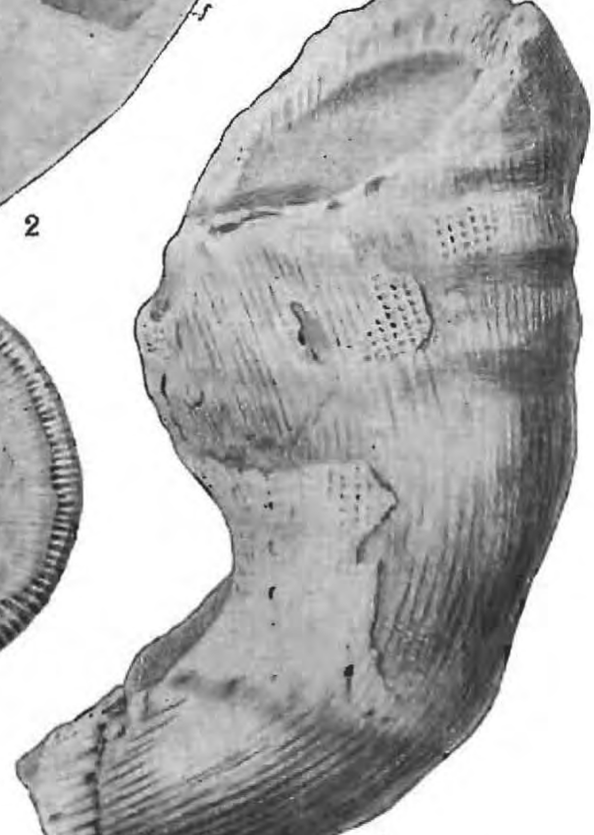
2a



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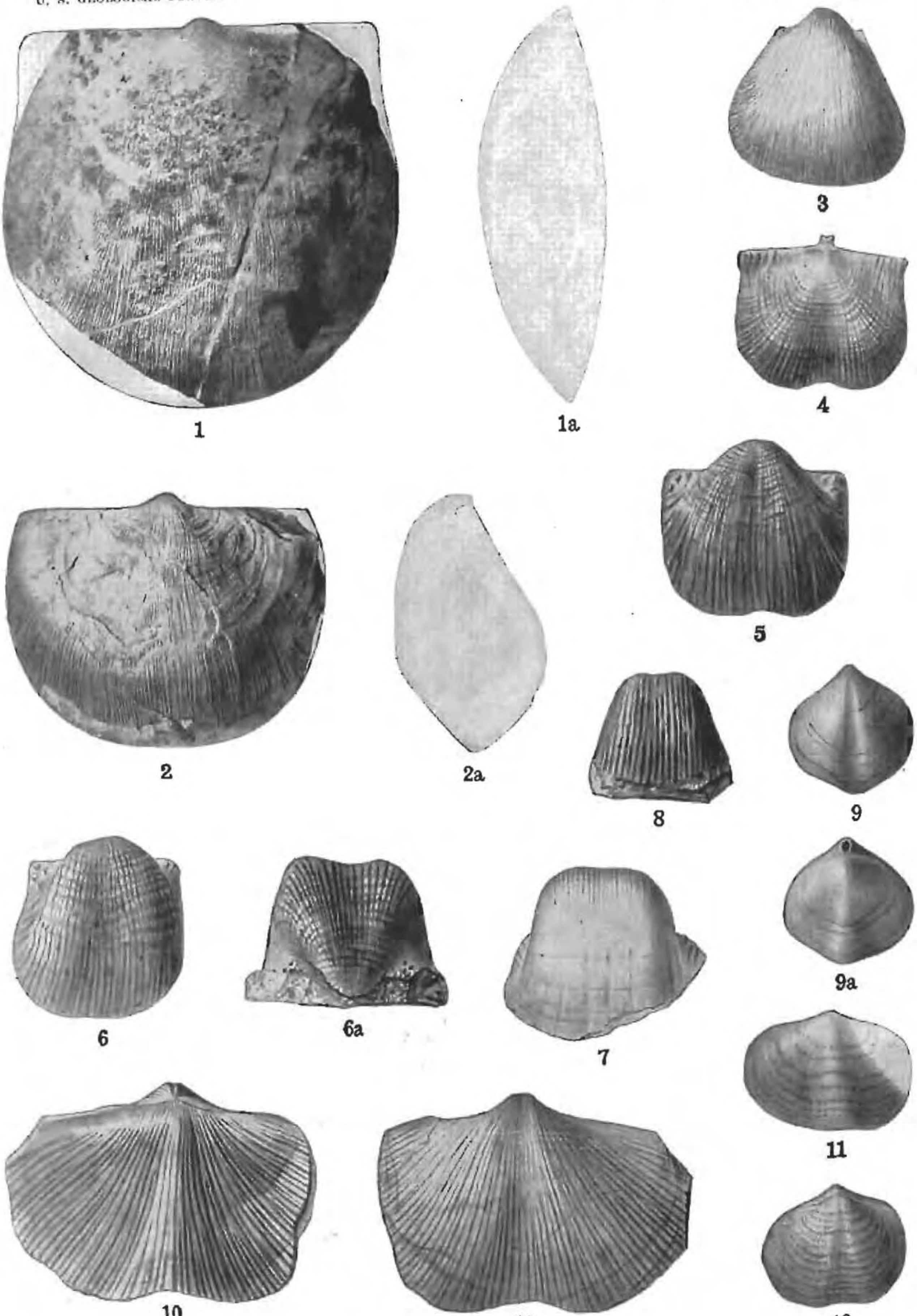
CHARACTERISTIC FOSSILS OF UPPER MISSISSIPPIAN AGE.



CHARACTERISTIC FOSSILS OF UPPER MISSISSIPPIAN AGE.

PLATE LIII.

Productus brazerianus Girty, n. sp. (pp. 643–644).

FIGURE 1. A large dorsal valve seen from above.
1a. Side view in outline.
2. A small ventral valve seen from above.
2a. Side view in outline.
The figured specimens are from the Wayan quadrangle in Idaho, but the same species occurs in the Wasatch Range in Utah.

Productus ovatus Hall.

FIGURE 3. A ventral valve seen from above.
After Hall and Whitfield, U. S. Geol. Expl. 40th Par. Final Rept., vol. 4, pt. 2, pl. 5, fig. 7, 1877. The figured specimen is from Dry Canyon, Oquirrh Mountains, Utah.

Productus burlingtonensis Hall.

FIGURE 4. Interior of a dorsal valve seen from above.
5. A ventral valve seen from above.
After Hall and Whitfield, U. S. Geol. Expl. 40th Par. Final Rept., vol. 4, pt. 2, pl. 5, figs. 9 and 10, 1877. The figured specimens are from Dry Canyon, Oquirrh Mountains, Utah. The identification given by Hall and Whitfield is no doubt incorrect, but the exact affinities have not been determined.

Productus semireticulatus Martin.

FIGURE 6. A ventral valve seen from above.
6a. Posterior view of same.
After Hall and Whitfield, U. S. Geol. Expl. 40th Par. Final Rept., vol. 4, pt. 2, pl. 5, figs. 5 and 6, 1877. The figured specimen is from Dry Canyon, Oquirrh Mountains, Utah. This may be only a coarse-ribbed variety of the species cited as *P. burlingtonensis*.

Productus semistriatus Meek.

FIGURE 7. Anterior-ventral view of the type specimen.
After Meek, Paleontology, U. S. Geol. Expl. 40th Par. Final Rept., vol. 4, pt. 1, pl. 7, fig. 8, 1877. The original specimen is from a locality southeast of Great Salt Lake, Utah.

Diaphragmus elegans Norwood and Pratten.

FIGURE 8. Anterior view of a ventral valve.
After Hall and Whitfield, U. S. Geol. Expl. 40th Par. Final Rept., vol. 4, pt. 2, pl. 5, fig. 4, 1877. The figured specimen is from Dry Canyon, Oquirrh Mountains, Utah.

Composita subquadrata Hall?

FIGURE 9. Ventral view.
9a. Dorsal view of the same.
After Hall and Whitfield, U. S. Geol. Expl. 40th Par. Final Rept., vol. 4, pt. 2, pl. 5, figs. 19 and 20, 1877. The figured specimen is from Dry Canyon, Oquirrh Mountains, Utah.

Spirifer striatus Martin.

FIGURE 10. Dorsal view.
10a. Ventral view of same.
After Hall and Whitfield, U. S. Geol. Expl. 40th Par. Final Rept., vol. 4, pt. 2, pl. 5, figs. 13 and 14, 1877. The figured specimen is from Dry Canyon, Oquirrh Mountains, Utah.

Reticularia setigera Hall.

FIGURE 11. A dorsal valve.
12. Ventral view of a smaller specimen that preserves the surface ornamentation.
After Hall and Whitfield, U. S. Geol. Expl. 40th Par. Final Rept., vol. 4, pt. 2, pl. 5, figs. 17 and 18, 1877. The figured specimens are from Dry Canyon, Oquirrh Mountains, Utah.

PLATE LIV.

MADISON.

Schuchertella aff. S. chemungensis Conrad.

FIGURE 1. A ventral valve having fine and even ribs.
After Hall and Whitfield, U. S. Geol. Expl. 40th Par. Final Rept., vol. 4, pt. 2, pl. 4, fig. 2, 1877. The figured specimen is from Logan Canyon, Wasatch Range, Utah.
2. A dorsal valve of unusual breadth, having ribs that alternate in size.
After Hall and Whitfield, U. S. Geol. Expl. 40th Par. Final Rept., vol. 4, pt. 2, pl. 4, fig. 1, 1877. The figured specimen is from Ogden Canyon, Wasatch Range, Utah.

Leptaena analoga Phillips.

FIGURE 3. A characteristic specimen showing the fine radial markings and the fine even concentric wrinkles.
After Hall and Whitfield, U. S. Geol. Expl. 40th Par. Final Rept., vol. 4, pt. 2, pl. 4, fig. 4, 1877. The figured specimen is from Dry Canyon, Oquirrh Mountains, Utah.

Chonetes loganensis Hall and Whitfield.

FIGURE 4. The type specimen, which is a ventral valve.
After Hall and Whitfield, U. S. Geol. Expl. 40th Par. Final Rept., vol. 4, pt. 2, pl. 4, fig. 9, 1877. The figured specimen is from Logan Canyon, Wasatch Mountains, Utah.

Spirifer centronatus Winchell.

FIGURE 5. A large dorsal valve.
6. A smaller ventral valve.
After Hall and Whitfield, U. S. Geol. Expl. 40th Par. Final Rept., vol. 4, pt. 2, pl. 4, fig. 5, 1877. The figured specimens are from Dry Canyon, Oquirrh Mountains, Utah.

Straparollus ophirensis Hall and Whitfield.

FIGURE 7. Side view of the typical specimen.
7a. The lower, or umbilical, side.
After Hall and Whitfield, U. S. Geol. Expl. 40th Par. Final Rept., vol. 4, pt. 2, pl. 4, figs. 26 and 27, 1877. The figured specimen is from Dry Canyon, Oquirrh Mountains, Utah.

Euomphalus laxus White.

FIGURE 8. Upper side.
8a. Profile of same.
After Hall and Whitfield, U. S. Geol. Expl. 40th Par. Final Rept., vol. 4, pt. 2, pl. 4, figs. 24 and 25, 1877. The figured specimen is from Dry Canyon, Oquirrh Mountains, Utah.

Euomphalus utahensis Hall and Whitfield.

FIGURE 9. Upper side of a rather small specimen represented by a gutta-percha impression.
After Hall and Whitfield, U. S. Geol. Expl. 40th Par. Final Rept., vol. 4, pt. 2, pl. 4, fig. 21, 1877. The figured specimen is from Dry Canyon, Oquirrh Mountains, Utah.

Proetus peroccidens Hall and Whitfield.

FIGURE 10. A rather small pygidium, × 2.
After Hall and Whitfield, U. S. Geol. Expl. 40th Par. Final Rept., vol. 4, pt. 2, pl. 4, fig. 32, 1877. The figured specimen is from Ogden Canyon, Wasatch Range Utah.

Proetus loganensis Hall and Whitfield.

FIGURE 11. The type specimen, a pygidium, × 2.
After Hall and Whitfield, U. S. Geol. Expl. 40th Par. Final Rept., vol. 4, pt. 2, pl. 4, fig. 33, 1877. The figured specimen is from Logan Canyon, Wasatch Range, Utah.

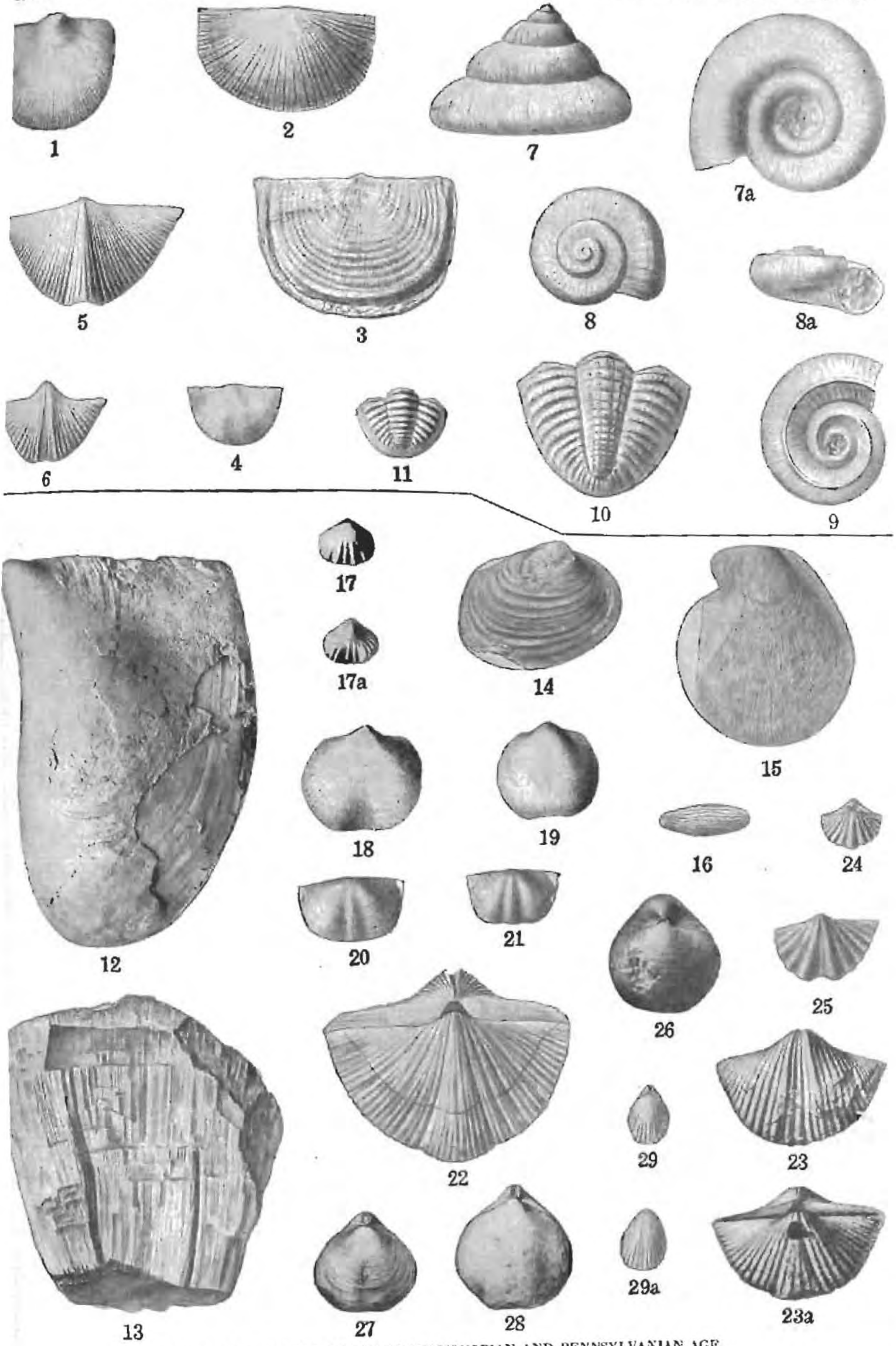
PENNSYLVANIAN.

Myalina subquadrata Shumard.

FIGURE 12. A left valve.
The figured specimen is from the Drum limestone at Drum, Kans.

Chaetetes milleporaceus Troost.

FIGURE 13. Side view of a broken specimen, showing the innumerable small tubes of which the coral is composed.
After White, U. S. Geog. and Geol. Surveys W. 100th Mer. Final Rept., vol. 4, pt. 1, pl. 6, fig. 2a, 1877. The figured specimen is from the Virgin Range, near St. George, Utah.



CHARACTERISTIC FOSSILS OF LOWER MISSISSIPPIAN AND PENNSYLVANIAN AGE.

Edmondia gibbosa McCoy.

FIGURE 14. A right valve.
After Girty, U. S. Geol. Survey Prof. Paper 16, pl. 9, fig. 8, 1903. The figured specimen from the Rico quadrangle, Colo.

Pseudomonotis kansasensis Beede.

FIGURE 15. A left valve.
After Girty, U. S. Geol. Survey Prof. Paper 16, pl. 8, fig. 4, 1903. The figured specimen is from the Rico quadrangle, Colo.

Fusulina cylindrica Fischer de Waldheim.

FIGURE 16. Side view, × 2.
After White, U. S. Geog. and Geol. Surveys W. 100th Mer. Final Rept., vol. 4, pt. 1, pl. 6, fig. 6a, 1877. The figured specimen is from an undesignated locality in Utah. The species is probably not true *Fusulina cylindrica*, though it is commonly cited under that name.

Pugnoides osagensis Swallow.

FIGURE 17. Dorsal view.
17a. Ventral view of the same.
After Girty, U. S. Geol. Survey Bull. 544, pl. 10, figs. 11 and 11c, 1915. The figured specimen is from the Coalgate quadrangle, Okla. The form may be, as it is commonly considered to be, the same as *Rhynchonella utah* of Marcou, but, if so, Marcou's figures must be very poor.

Schizophoria resupinoides Cox?

FIGURE 18. A ventral valve.
19. A smaller dorsal valve.
After White, U. S. Geog. and Geol. Surveys W. 100th Mer. Final Rept., vol. 3, Suppl., Appendix, pl. 3, figs. 2a and 2b, 1881. The figured specimens are from Manuelitos Creek, N. Mex. This species is not *Schizophoria resupinoides* of Cox and may prove to belong to Mather's *Schizophoria altirostris*.

Chonetes mesolobus var. decipiens Girty.

FIGURE 20. View of a ventral valve.
21. View of another ventral valve.
After Girty, U. S. Geol. Survey Prof. Paper 16, pl. 1, figs. 20 and 22, 1903. The figured specimens are from the Durango quadrangle, Colo.

Spirifer triplicatus Hall (p. 645).

FIGURE 22. Dorsal view.
After White, U. S. Geog. and Geol. Surveys W. 100th Mer. Final Rept., vol. 4, pt. 1, pl. 10, fig. 1a, 1877. The figured specimen is from near Santa Fe, N. Mex.

Spirifer rockymontanus Marcou.

FIGURE 23. Ventral view of a specimen of medium size.
23a. Dorsal view.
After Girty, U. S. Geol. Survey Prof. Paper 16, pl. 6, figs. 1 and 1a, 1903. The figured specimen is from the Durango quadrangle, Colo. The identification adopted is the current one. Marcou may have included two distinct species in his *Spirifer rockymontanus*, and the form figured here may not be identical with either of them.

Spiriferina kentuckyensis Shumard.

FIGURE 24. Dorsal view of a specimen.
25. Ventral view of an unsymmetrical specimen enlarged to 2 diameters.
After White, U. S. Geog. and Geol. Surveys W. 100th Mer. Final Rept., vol. 4, pl. 10, figs. 4a and 4c, 1877. The figured specimens are from an undesignated locality in the Great Basin region.

Squamularia perplexa McChesney.

FIGURE 26. Dorsal view.
After Girty, U. S. Geol. Survey Bull. 544, pl. 11, fig. 2, 1915. The figured specimen is from the Coalgate quadrangle, Okla. Most specimens of this species are smaller than the one figured, and rather broader.

Composita subtilita Hall.

FIGURE 27. Dorsal view.
28. Dorsal view of a larger and longer specimen.
After Girty, U. S. Geol. Survey Prof. Paper 16, pl. 7, figs. 4 and 6, 1903. The figured specimens are from the Durango quadrangle, Colo.

Hustedia mormoni Marcou.

FIGURE 29. Dorsal view.
29a. Ventral view of same.
After White, U. S. Geog. and Geol. Surveys W. 100th Mer. Final Rept., vol. 4, pl. 10, figs. 7a and 7b, 1877. The figured specimen appears to be from an undesignated locality in New Mexico or Nevada. Marcou's original specimens are said to have come from Utah.

PLATE LV.

Productus cora D'Orbigny.

FIGURE 1. The type specimen, a ventral valve, seen from above, × 1½.

1a. Side view of same, × 1½.

After Tschernyschew, in Com. geol. [Petrograd] Mém., vol. 16, No. 2, p. 289, figs. A and B, 1902. The specimen is from Yarbichambi (?), Bolivia.

2. Side view of a typical specimen.

2a. Dorsal view.

2b. Posterior view.

2c. Ventral view.

After Kozlowski, in Annales de paléontologie, vol. 9, pl. 6, figs. 1a, 1b, 1c, 1d, 1914. The figured specimen is from Yarbichambi, Bolivia.

Productus inflatus var. coloradoensis Girty.

FIGURE 3. Ventral view.

4. Dorsal view of another specimen.

After Girty, U. S. Geol. Survey Prof. Paper 16, pl. 3, figs. 1 and 3, 1903. The figured specimens are from the Leadville district, Colo.

Marginifera splendens Norwood and Pratten.

FIGURE 5. Dorsal view.

5a. Ventral view.

After Girty, U. S. Geol. Survey Bull. 544, pl. 10, figs. 2 and 2b, 1915. The figured specimen is from the Wewoka quadrangle, Okla.

Marginifera muricata Norwood and Pratten.

FIGURE 6. Dorsal view.

7. Ventral view of another, more coarsely ribbed specimen.

After Girty, U. S. Geol. Survey Bull. 544, pl. 10, figs. 3 and 4, 1915. The figured specimens are from the Wewoka quadrangle, Okla.

Pustula nebraskensis Owen.

FIGURE 8. Ventral view of an exfoliated specimen.

9. Dorsal view of a smaller, more perfectly preserved specimen.

After Girty, U. S. Geol. Survey Prof. Paper 16, pl. 5, figs. 1 and 2, 1903. The figured specimens are from the Durango quadrangle, Colo.

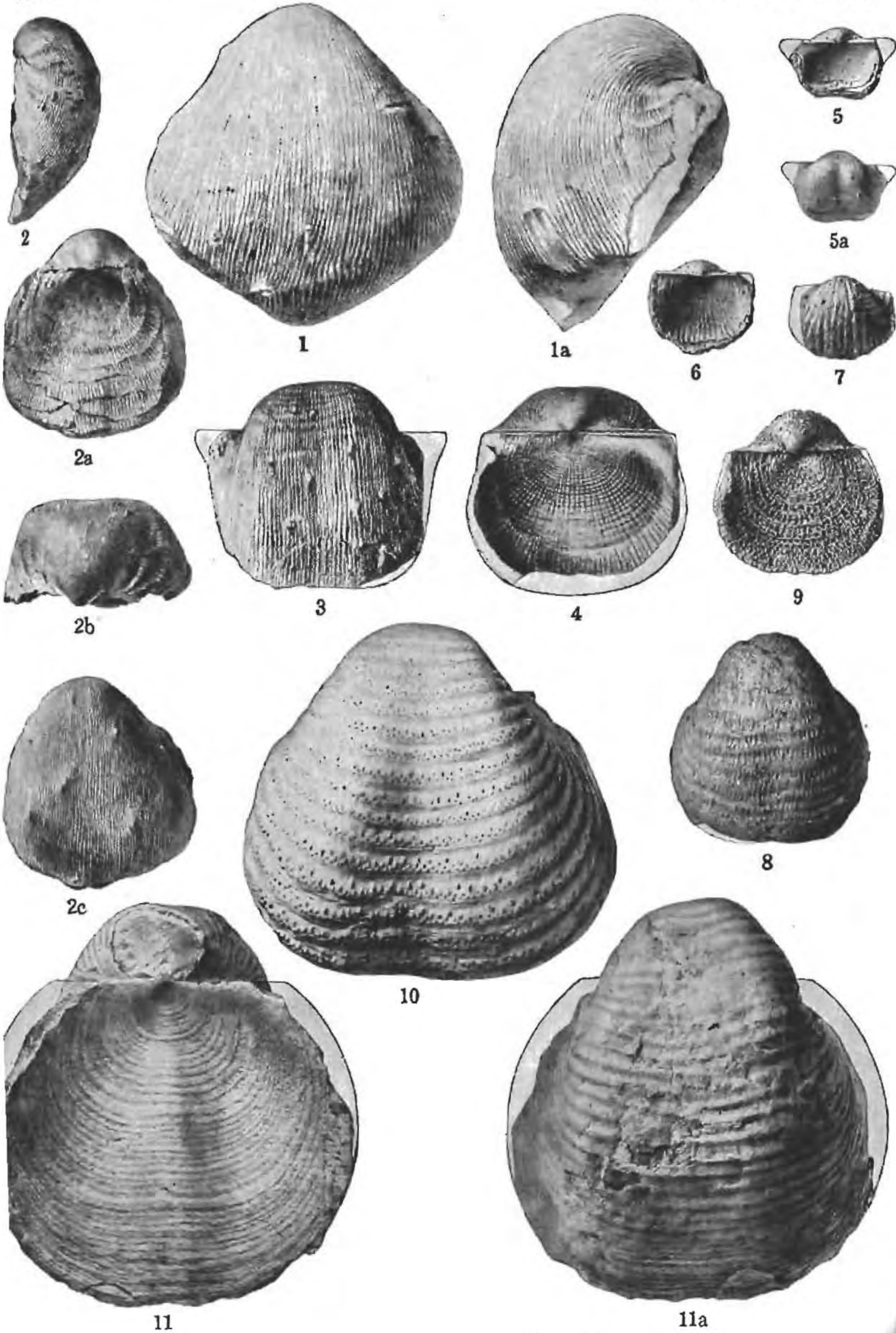
Pustula semipunctata Shepard.

FIGURE 10. A ventral valve with well-preserved surface, seen from above, × 1½.

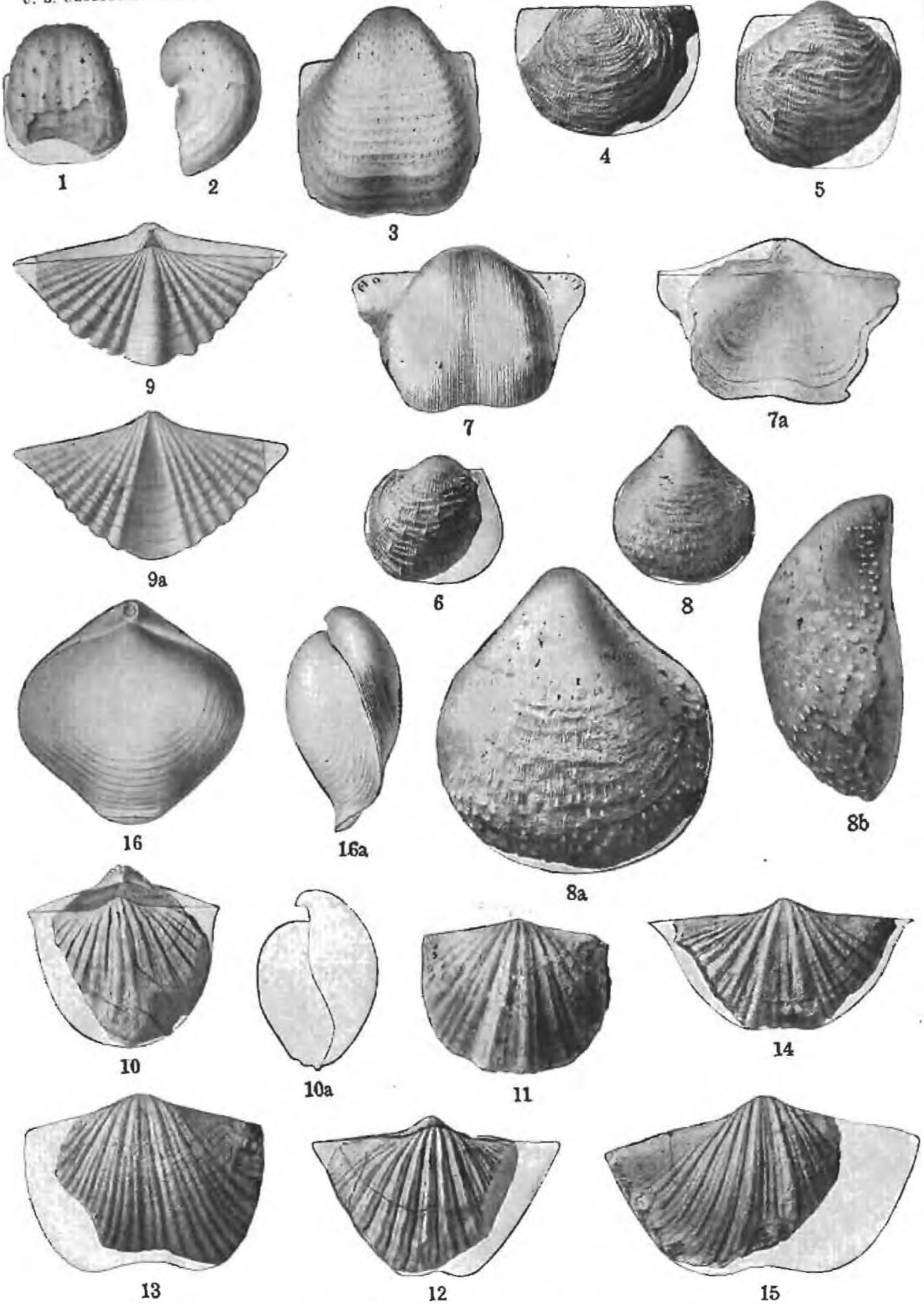
11. Dorsal view of a characteristic specimen.

11a. Ventral view of same.

The figured specimens are from the Iola limestone, at Iola, Kans.



CHARACTERISTIC FOSSILS OF PENNSYLVANIAN AGE.



CHARACTERISTIC FOSSILS OF PERMIAN AGE.

PLATE LVI.

Pustula subhorrida Meek.

FIGURE 1. Front view of a ventral valve.

2. Side view of another ventral valve.

After Meek, U. S. Geol. Expl. 40th Par. Final Rept., vol. 4, pt. 1, pl. 7, figs. 3 and 3a, 1877. The figured specimens are from an undesignated locality in the Great Basin region.

Pustula nevadensis Meek.

FIGURE 3. Ventral valve seen from above.

After Meek, U. S. Geol. Expl. 40th Par. Final Rept., vol. 4, pt. 1, pl. 8, fig. 2b, 1877. The figured specimen is from an undesignated locality in Nevada.

Productus phosphaticus Girty.

FIGURE 4. External mold of a dorsal valve.

5. A characteristic ventral valve.

6. A ventral valve showing numerous spines that spring from raised costae.

After Girty, U. S. Geol. Survey Bull. 436, pl. 2, figs. 7-9, 1910. The figured specimens are from Montpelier, Idaho.

Productus multistriatus Meek.

FIGURE 7. Ventral view of a characteristic specimen.

7a. Dorsal view of the same.

After Meek, U. S. Geol. Expl. 40th Par. Final Rept., vol. 4, pt. 1, pl. 8, figs. 3b and 3c, 1877. The figured specimens are from an undesignated locality in Nevada.

Aulosteges hispidus Girty, n. sp. (p. 644).

FIGURE 8. The typical specimen, a ventral valve, seen from above.

8a. Same, × 2.

8b. Side view, × 2.

The figured specimen is from Weber Canyon, Wasatch Range, Utah.

Spiriferina pulchra Meek.

FIGURE 9. Dorsal view of the original typical specimen.

9a. Ventral view.

After Meek, U. S. Geol. Expl. 40th Par. Fina Rept., vol. 4, pt. 1, pl. 8, figs. 1 and 1a, 1877. The figured specimen is from Nevada.

Spirifer pseudocameratus Girty, n. sp. (p. 644).

FIGURE 10. Dorsal view of a narrow specimen.

10a. Side view in outline.

11. Dorsal view of a characteristic specimen.

12. Dorsal view of a specimen that has the fold deeply divided.

13. A ventral valve of somewhat different type.

14. A ventral valve that is uncommonly wide at the hinge.

15. An imperfect ventral valve.

The figured specimens are from Weber Canyon, Wasatch Range, Utah.

Composita mira Girty (p. 646).

FIGURE 16. Dorsal view of a large specimen accidentally compressed.

16a. Side view of same.

After Meek, U. S. Geol. Expl. 40th Par. Final Rept., vol. 4, pt. 1, pl. 9, figs. 3 and 3b, 1877. The figured specimen is from an undesignated locality in Nevada.

PLATE LVII.

Aviculipecten utahensis Meek.

FIGURE 1. A left (?) valve, natural size.

1a. A portion of the surface of the same, magnified to show the minute, crowded, concentric striae.

After Meek, U. S. Geol. Expl. 40th Par. Final Rept., vol. 4, pt. 1, pl. 9, figs. 7, 7a, 1877. The figured specimen is from eastern Nevada.

Aviculipecten weberensis Hall and Whitfield.

FIGURE 2. View of a left valve, showing the strongly alternating coarser and finer sculpture.

After Hall and Whitfield, U. S. Geol. Expl. 40th Par. Final Rept., vol. 4, pt. 2, pl. 6, fig. 5, 1877. The figured specimen is from the foothills of the Wasatch Range, southeast of Salt Lake City, Utah.

Aviculipecten parvulus Hall and Whitfield.

FIGURE 3. Figure of a left valve, $\times$ 3, showing the strong, elevated, primary rays, with finer ones between.

After Hall and Whitfield, U. S. Geol. Expl. 40th Par. Final Rept., vol. 4, pt. 2, pl. 6, fig. 6, 1877. The figured specimen is from the foothills of the Wasatch Range, southeast of Salt Lake City, Utah.

Aviculipecten curticardinalis Hall and Whitfield.

FIGURE 4. The type specimen, $\times$ 2.

After Hall and Whitfield, U. S. Geol. Expl. 40th Par. Final Rept., vol. 4, pt. 2, pl. 6, fig. 4, 1877. The figured specimen is from the foothills of the Wasatch Range, southeast of Salt Lake City, Utah.

Aviculipecten occidaneus Meek.

FIGURE 5. A small left valve, $\times$ 2.

6. A left valve which has the anterior ear broken away.

After Meek, U. S. Geol. Expl. 40th Par. Final Rept., vol. 4, pt. 1, pl. 12, figs. 13, 13a, 1877. The figured specimens are from Weber Canyon in the Wasatch Range, Utah.

Aviculipecten? deseret Girty, n. sp. (p. 647).

FIGURE 7. A small left (?) valve, seen from above.

7a. Same, $\times$ 2.

8. An imperfect specimen that has well-preserved sculpture. Seen from above, $\times$ 4.

9. A characteristic left (?) valve, seen from above.

9a. Same, $\times$ 2.

The figured specimens are from Dry Canyon in the Wasatch Range, east of Salt Lake City, Utah.

Sedgwickia? concava Meek and Hayden.

FIGURE 10. A right valve, as obtained by a gutta-percha impression in the natural mold.

After Hall and Whitfield, U. S. Geol. Expl. 40th Par. Final Rept., vol. 4, pt. 2, pl. 6, fig. 3, 1877. The figured specimen is from the foothills of the Wasatch Range, southeast of Salt Lake City, Utah.

Myacites inconspicuus Meek.

FIGURE 11. A left valve, $\times$ 2.

After Meek, U. S. Geol. Expl. 40th Par. Final Rept., vol. 4, pt. 1, pl. 12, fig. 10, 1877. The figured specimen is from Weber Canyon in the Wasatch Range, Utah. This figure so much resembles Hall and Whitfield's figure of *Sedgwickia? concava* as to suggest strongly that they are the same species. Hall and Whitfield's fossil is without much doubt wrongly identified; if it is the same as *Myacites inconspicuus*, it will go into the synonymy of that species; if it is not the same it is probably a new species.

Astartella? forresteri Girty.

FIGURE 12. Right valve of a typical specimen, $\times$ 2.

12a. Same in outline, natural size.

12b. Anterior view, $\times$ 2.

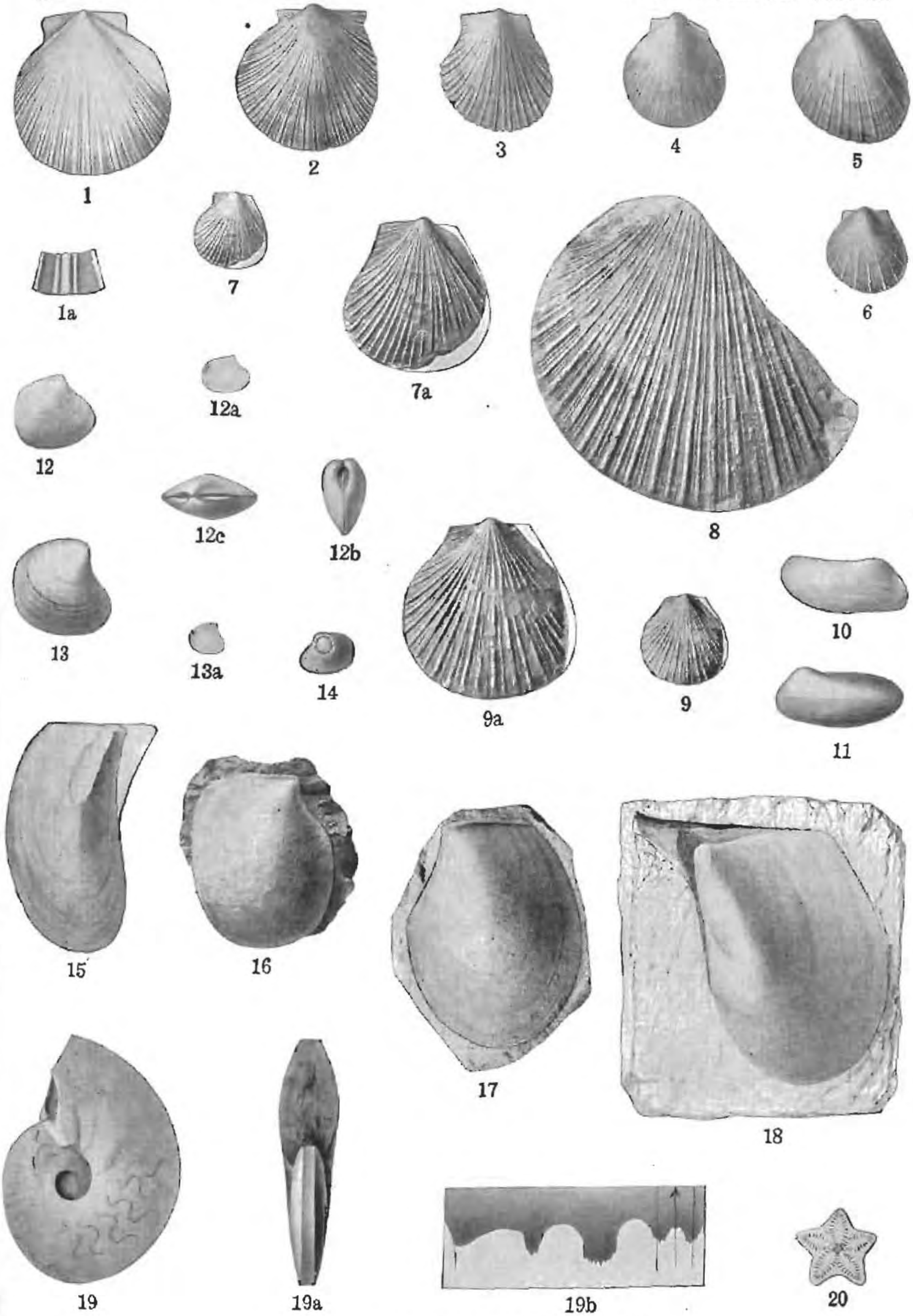
12c. Cardinal view, $\times$ 2.

13. Right valve of a differently shaped specimen, $\times$ 2.

13a. Same in outline, natural size.

14. Left valve of a large specimen with an extended anterior end.

The figured specimens are from near Torrey, Wayne County, Utah.



CHARACTERISTIC FOSSILS OF LOWER TRIASSIC AGE.

Myalina permiana Swallow.

FIGURE 15. View of a mold of a right valve, showing the usual form. The outline at the beak shows the extreme of other specimens.

After Hall and Whitfield, U. S. Geol. Expl. 40th Par. Final Rept., vol 4, pt. 2, pl. 6, fig. 7, 1877. The figured specimen is from the foothills of the Wasatch Range, southeast of Salt Lake City, Utah. The identification quoted above is almost certainly erroneous, and the species is probably a new one.

Myalina? platynotus White (p. 648).

FIGURE 16. A rather short and broad right valve.

17. A characteristic left valve.

The figured specimens are from the base of the Thaynes limestone, Park City district, Utah.

Myalina aviculoides Meek and Hayden.

FIGURE 18. View of an internal mold of a left valve with the impression of the extended beak showing in the matrix.

After Hall and Whitfield, U. S. Geol. Expl. 40th Par. Final Rept., vol. 4, pt. 2, pl. 6, fig. 8, 1877. The figured specimen is from the foothills of the Wasatch Range, southeast of Salt Lake City, Utah. The identification quoted above is almost certainly erroneous, and the species is probably a new one.

Meekoceras gracilitatis White.

FIGURE 19. Side view of a rather small specimen.

19a. Front view of same.

19b. Suture of same, × 2.

After Hyatt and Smith, U. S. Geol. Survey Prof. Paper 40, pl. 12, figs. 7, 8, and 10. The figured specimen is from Aspen Ridge, near Soda Springs, Idaho, but very similar specimens occur in limestones supposed to represent the Thaynes limestone, in the Wasatch Range, Utah.

Pentacrinus asteriscus Meek and Hayden?

FIGURE 20. View of a disk referred with doubt to this species, × 2.

After Hall and Whitfield, U. S. Geol. Expl. 40th Par. Final Rept., vol. 4, pt. 2, pl. 6, fig. 16, 1877. The figured specimen is from the Pah-Ute Range, Nev. Star-shaped crinoid stems similar to this, though probably not the same species, are rather characteristic of the lower Triassic rocks of Idaho and Utah. They occur, for instance, in the Thaynes limestone of the Park City district.

INDEX.

H.

I.

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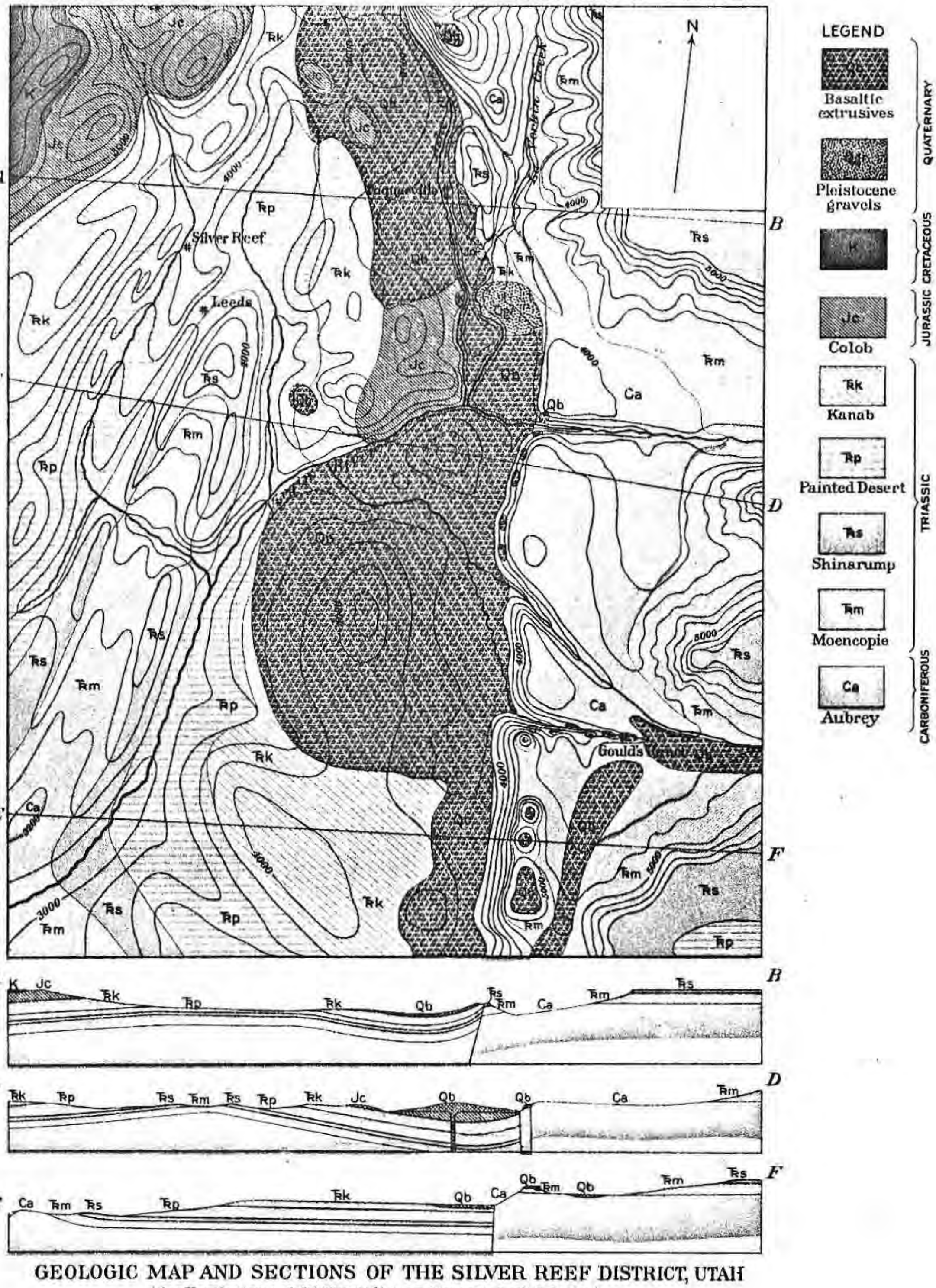


GEOLOGIC MAP AND SECTIONS OF THE SILVER REEF DISTRICT, UTAH

After Huntington and Goldthwait (Age assignments by B. S. Butler)

1 ½ 0 1 2 3 4 5 Miles

Contour interval 200 feet

Datum is mean sea level

1918

G.W. Crane

WATER-POWER PLANTS OF POWER SYSTEMS OPERATING IN UTAH.

1 Georgetown, Georgetown Creek
2 High Creek, Cub Creek
3 Paris, Paris Creek
4 Grace, Bear River
5 Cove, Bear River
6 Oneida, Bear River
(1–6: In Idaho)
7 Devils Gate, Weber River
8 Ogden, Ogden River
9 Granite, Big Cottonwood Creek
10 Stairs, Big Cottonwood Creek
11 Alpine, Dry Creek
12 Lower American Fork, American Fork
13 Upper American Fork, American Fork
14 Battle Creek, Battle Creek
15 Collinston, Bear River
16 Davis, Farmington Creek
17 Jordan Narrows, Jordan River
18 Logan, Logan River
19 Murdock, Provo River
20 Upper Mill Creek, Mill Creek
21 Lower Mill Creek, Mill Creek
22 Olmstead, Provo River
23 Park City, Ontario Tunnel
24 Riverdale, Weber River
25 Santaquin, Santaquin Creek
26 Snake Creek, Snake Creek
27 Hyrum, Blacksmith Fork
28 Williard, Williard Creek
29 Beaver River, Beaver River
30 Bennion's, Jordan River
31 Big Springs, Big Springs Creek
32 Cedar City, Cole Creek
33 Tooele, Settlement Creek
34 Morgan
35 Orangeville
36 Gunnison, Sixmile Creek
37 Lower Fish Creek, Fish Creek
38 Upper Fish Creek, Fish Creek
39 Kundsen, Big Cottonwood
40 State Street, Big Cottonwood
41 Spring City, Oak Creek
42 Swan Creek, Swan Creek
43 Spanish Fork, Spanish Fork
44 Vernal, Ashley Creek
45 Alta, Little Cottonwood Creek
46 Beaver, Beaver River
47 Brigham, Boxelder Creek
48 Ephraim, Cottonwood Creek
49 Fairview, Cottonwood
50 Heber, Provo River
51 Helper, Price River
52 Hyrum, Blacksmith Fork
53 Logan, Logan River
54 Manti, Manti Creek
55 Monroe, Monroe Creek
56 Mount Pleasant, Pleasant Creek
57 Murray, Little Cottonwood Creek
58 Nephi, Salt Creek
59 Parowan, Center Creek
60 Springville, Hobble Creek
61 St. George, Cottonwood Creek
62 Utah State, Logan River
63 Alta, Little Cottonwood Creek
64 Ophir, Ophir Creek
65 South Willow Creek, South Willow Creek
66 Kimberly, Clear Creek
67 Salina, Saline Creek
68 Nephi Plaster and Manufacturing Co., Salt Creek

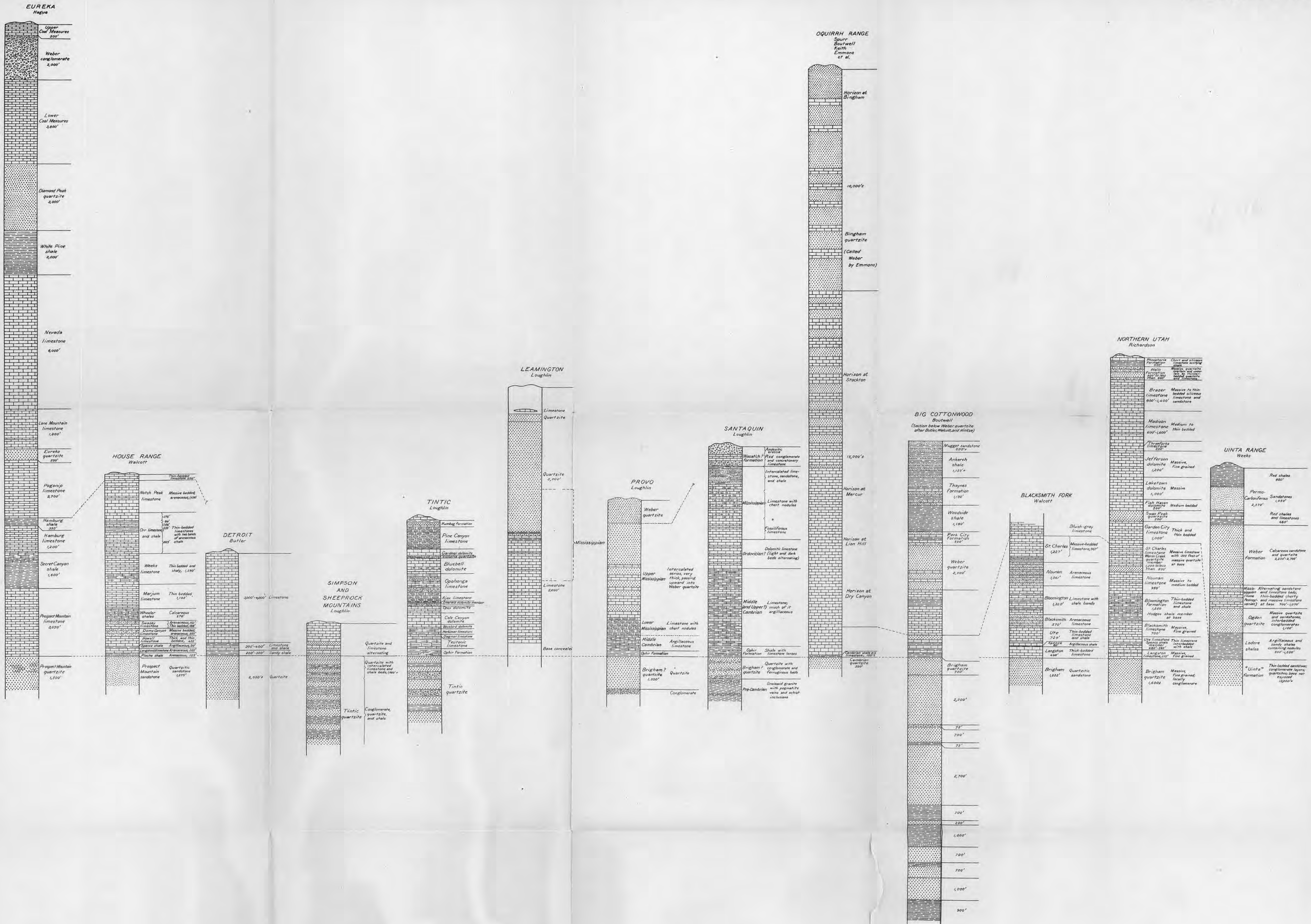
Base from General Land Office map of Utah
Contours adjusted from U.S. Geological Survey map of Utah published in 1899 and later topographic maps.

SNYDER & BLACK, N.Y.

Power plants and transmission lines by Herman Stabler.
Mining districts by B.S. Butler and G.F. Loughlin

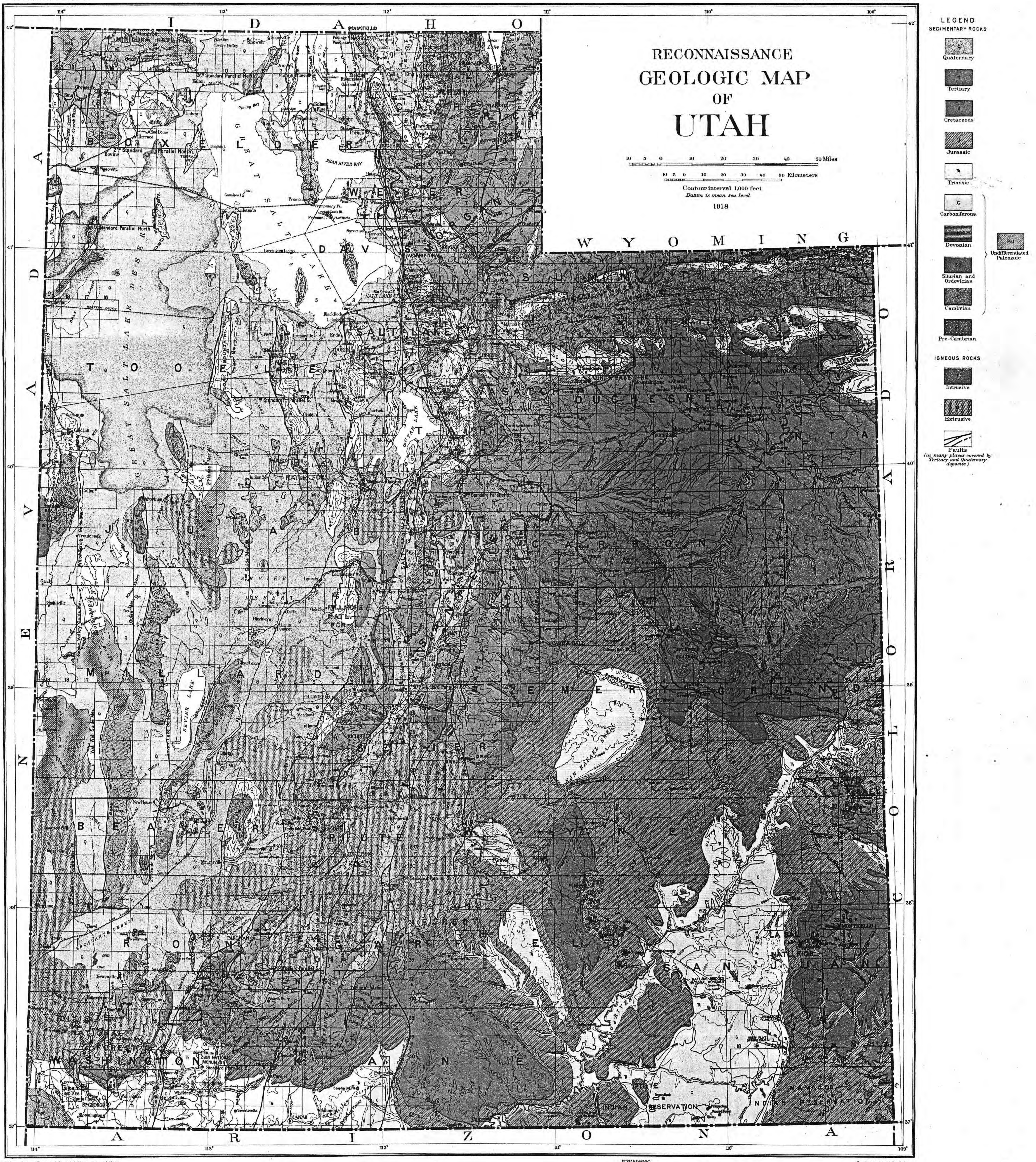
MINING DISTRICTS IN UTAH.

	NAME OF DISTRICT	COUNTY
44	Adams (see Hot Springs)	Salt Lake
1	Alpine	Utah
2	American Fork	Utah
3	Antelope	Beaver
4	Argenta	Morgan
5	Ashbrook	Boxelder
6	Beaver Lake	Beaver
7	Big Cottonwood	Salt Lake
8	Big Indian	San Juan
9	Black Crook or Erickson	Tooele
10	Blue Bell	Tooele
11	Blue Ledge	Wasatch
12	Blue Mountain (Monticello)	San Juan
13	Bolter or Boulder	Tooele
14	Box Elder	Boxelder
15	Bradshaw	Beaver
16	Bull Valley	Washington
17	Camp Floyd (Mercur)	Tooele
18	Carbonate	Uinta
19	Castle Peak	Wasatch
20	Clifton (Gold Hill)	Tooele
21	Colorado River	San Juan, Garfield, and Kane
22	Columbia	Tooele
23	Coyote Creek	Garfield
24	Deseret (Desert Mountain)	Juab
25	Detroit (Joy) (Drum, 1872)	Juab and Millard
26	Dugway	Tooele
27	Elkhorn	Wasatch
28	Emery (Lost Springs)	Emery
9	Erickson (see Black Crook)	Tooele
29	Farmington	Davis
30	Fish Springs	Juab
31	Free Coinage	Tooele
32	Fremont Island	Weber
33	Gold Mountain (Kimberly)	Piute
34	Gold Springs	Iron
35	Gordon	Millard and Beaver
36	Granite	Beaver
37	Granite Mountains	Tooele
38	Grantsville	Tooele
39	Greeley (south of Camp Floyd)	Tooele
40	Green River	Uinta
41	Hardscrabble (Mill Creek)	Morgan
42	Harrisburg (Silver Reef)	Washington
43	Henry	Sevier
44	Hot Springs (includes Adams)	Salt Lake
45	Indian Peak	Beaver
46	Iron Springs	Iron
47	Johnson Peak (Trout Creek)	Juab
48	Juab	Juab
49	Lakeside	Tooele
50	La Sal	Grand
51	Leamington (Oak City)	Millard
52	Lehi	Utah
53	Lincoln	Beaver
54	Little Cottonwood (Alta)	Salt Lake
55	Little Grande	Grand
56	Lower Placer	Salt Lake
57	Lucin	Boxelder
58	McGarry	Beaver
59	Marble	Summit
41	Mill Creek (see Hardscrabble)	Morgan
60	Miners Basin	Grand
61	Mona	Juab
62	Monumental	San Juan
63	Morgan	Morgan
64	Mount Baldy	Piute
65	Mount Nebo (Timmons)	Juab
66	Newfoundland	Boxelder
67	Newton	Beaver
36	North Granite (see Granite)	Beaver
98	North Star (see Star)	Beaver
68	North Tintic (Oasis in 1873 and Caledonia in 1875)	Tooele and Utah
68	Oasis (Caledonia)	Tooele
69	Ohio (Marysvale)	Piute
70	Ophir	Tooele
71	Osceola (south of Camp Floyd)	Tooele
72	Paradise (La Plata)	Cache
73	Park Valley	Boxelder
74	Payson	Utah
75	Pine Grove	Beaver
76	Pinto Iron (Silver Belt)	Iron
77	Promontory	Boxelder
78	Provo	Utah
79	Preuss (Newhouse)	Beaver
80	Richardson	Grand
81	Richmond	Cache
82	Rhodes Plateau (Woodland)	Wasatch
83	Rocky	Beaver
84	Rosebud	Boxelder
85	Rush Valley (Stockton)	Tooele
86	Salina Creek	Sevier
87	San Francisco (Frisco)	Beaver
88	San Rafael	Emery
89	Santa Clara	Washington
90	Santaquin	Utah
91	Saw Back	Millard
92	Sierra Madre	Weber and Boxelder
93	Silver Islet	Tooele
94	Silver Lake	Utah
95	Snake Creek (formerly White Pine, Howland)	Wasatch
96	Spanish Fork	Utah
97	Spring Creek	Juab
98	Star (known as South Star)	Beaver
99	Smelter	Salt Lake
100	Stateline	Iron
101	Sterling	Beaver
102	Sulphur	Beaver
38	Third Term (see Grantsville)	Tooele
103	Tidewell & Rideout	Carbon
65	Timmons (see Mount Nebo)	Juab
104	Tintic	Juab and Utah
105	Tooele	Tooele
106	Tutsagubet	Washington
107	Uintah (Park City)	Summit
108	Utah	Utah
109	Washington	Beaver
110	Weber (formerly Junction, 1860)	Weber
111	West Mountain (Bingham)	Salt Lake
112	West Tintic	Juab
113	Wheeler Desert	Grand
114	White Canyon (Hite)	Garfield and San Juan
115	Willard	Boxelder
116	Willow Springs	Tooele



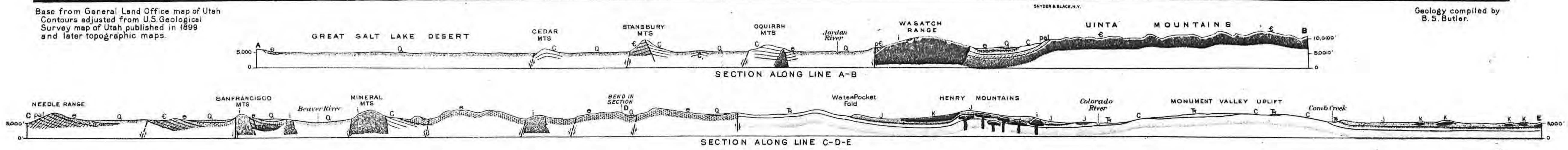
CORRELATED GEOLOGIC COLUMNAR SECTIONS OF NORTHERN UTAH

SNYDER & BLACK, N.Y.



Base from General Land Office map of Utah
Contours adjusted from U.S. Geological Survey map of Utah published in 1899 and later topographic maps.

Geology compiled by B. S. Butler.



CORRELATED GEOLOGIC COLUMNAR SECTIONS OF SOUTHERN UTAH
AND ADJACENT PARTS OF COLORADO, ARIZONA, AND NEVADA.

SNYDER & BLACK, N.Y.

CORRELATED GEOLOGIC COLUMNAR SECTIONS OF SOUTHERN UTAH AND ADJACENT PARTS OF COLORADO, ARIZONA, AND NEVADA.

SNYDER & BLACK, N.Y.

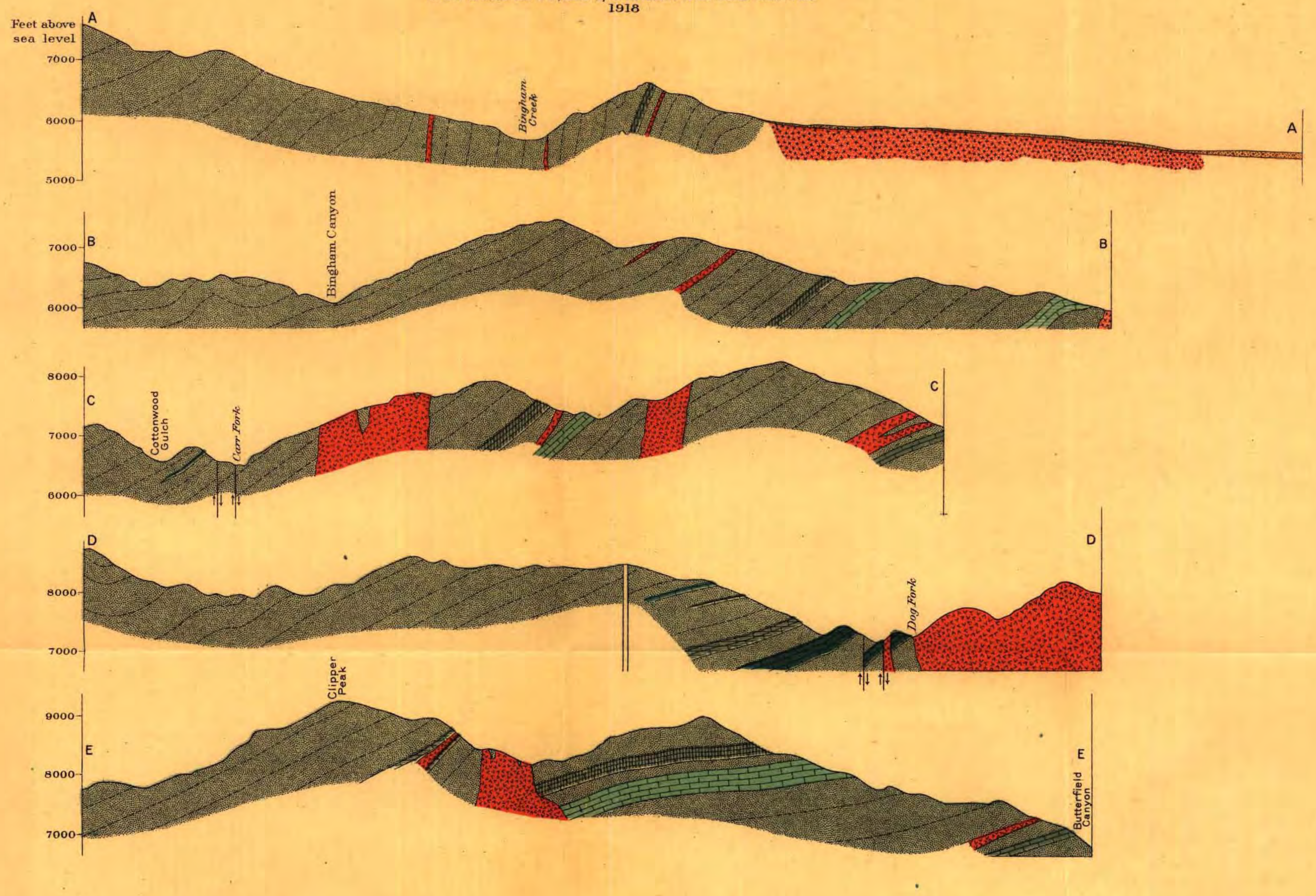
R. U. Goode, Geographer in charge
Triangulation by R. U. Goode
Topography by W. J. Peters, E. T. Perkins, Jr., and Jeremiah Ahern
Surveyed in 1899-1900

GEOLOGIC MAP AND SECTIONS OF THE BINGHAM MINING DISTRICT, UTAH

Geology by Arthur Keith and J. M. Boutwell
Surveyed in 1900

Scale
0 1000 2000 3000 4000 5000 6000 7000 feet
0 500 1000 1500 2000 meters

Contour interval 50 feet
Datum is mean sea level, based upon elevations of Rio Grande Western R.R.
1918



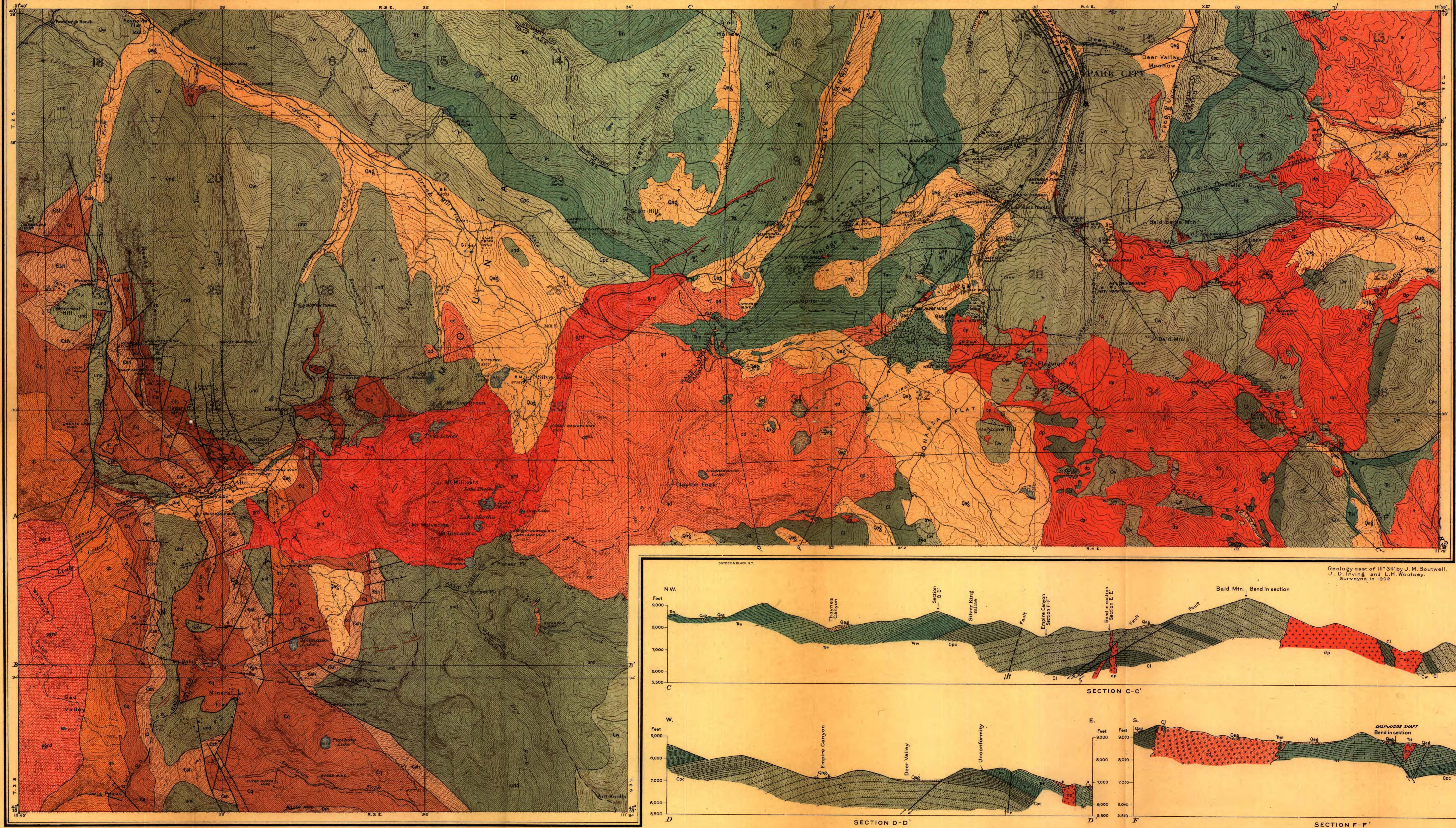
IGNEOUS ROCKS

POST-CARBONIFEROUS

- a — **Andesite** (*Great series of extrusive lava flows with sediments, coal, and waterworn gravels, interbedded locally*)
- dp — **Quartz diorite porphyry** (*Irregular stocks and dikes*)
- qd — **Quartz diorite** (*Extensive stock*)
- grd — **Granodiorite**
- pgrd — **Porphyritic granodiorite**
- d — **Dikes** (*Various intrusive rocks*)

SYMBOLS

- Known formation boundary
- Probable formation boundary
- Dip and strike of strata
- Known fault
- Probable fault
- Dip of fault plane
- Downthrown side of normal or drop fault and overridden side of thrust fault
- Shaft
- Tunnel
- Prospect
- Mine dump



Base from Cottonwood and Park City topographic maps

Geology west of 111° 34' by B. S. Butler, F. C. Calkins, F. F. Hintze, and G. F. Loughlin

LEGEND

SEDIMENTARY ROCKS

QUATERNARY — *Pleistocene and Recent*

- Qag — **Alluvium and glacial deposits**

JURASSIC OR TRIASSIC

- Ŧn — **Nugget sandstone** (*Coarse, pebbly, white sandstone containing petrified wood*)

TRIASSIC — *Lower Triassic*

- Ŧa — **Ankareh shale** (*Chiefly red shale, ripple marked and mud cracked, including thin beds of white sandstone and gray limestone*)
- Ŧt — **Thaynes formation** (*Comprises limestones, calcareous sandstones, and shales; more calcareous upper portion separated from more sandy lower by "mid-red" shales. Abundant fossils*)
- Ŧw — **Woodside shale** (*Uniformly fine-grained dark-red shales*)
- Ŧm — **Metamorphic sediments** (*Includes limestone, marble, sandstone, argillites, etc. Age unknown, probably Triassic*)

CARBONIFEROUS — *Permian*, *Pennsylvanian*

- Cpc — **Park City formation** (*Mainly pure, blue, cherty, and gray limestones; minor quantities of shale and sandstone*)
- Cw — **Weber quartzite** (*Massive-bedded light-gray quartzite with few intercalated limestone beds*)
- Cl — **Undifferentiated limestones in Park City district** (*include intercalated members in Weber quartzite and isolated blocks in igneous rocks*)

PALEOZOIC

- und — **Undifferentiated limestones in Cottonwood district** (*Mainly Carboniferous, but probably in part Devonian; include Cambrian limestone where this is not separated*)

CAMBRIAN

- Єl — **Limestone** (*Separately mapped only near Alta*)
- Єsh — **Shale and interbedded limestone**
- Єq — **Quartzite** (*Includes some pre-Cambrian near American Fork*)

PRE-CAMBRIAN

- qt — **Quartzite and tillite**

- Ŧtm, Ŧwm, Cpm — **Contact-metamorphic zones**
  Ŧtm, marble in Thaynes formation
  Ŧwm, argillite in Woodside shale
  Cpm, marble in Park City formation

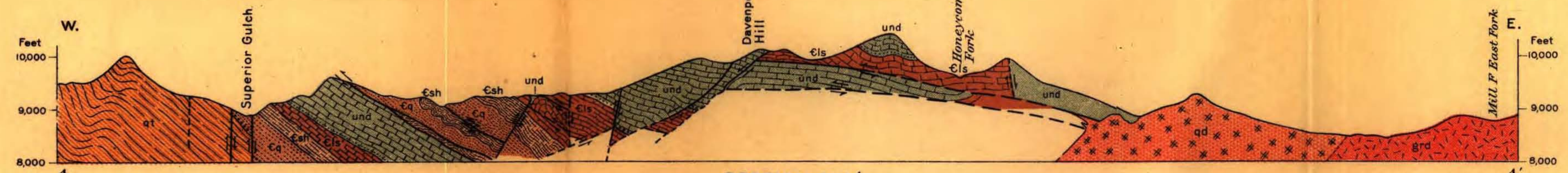
(*Legend continued on left margin*)

Geology east of 111° 34' by J. M. Boutwell, J. D. Irving, and L. H. Woolsey. Surveyed in 1903

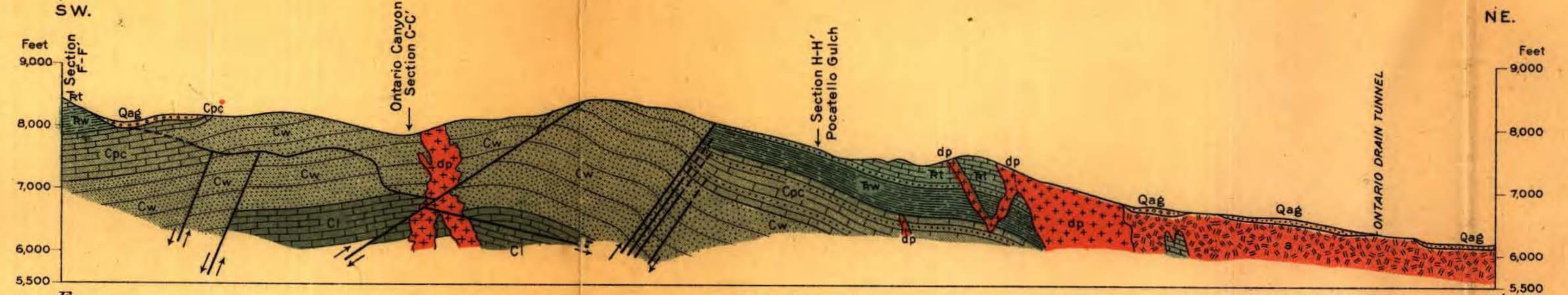
SECTION C-C'

SECTION D-D'

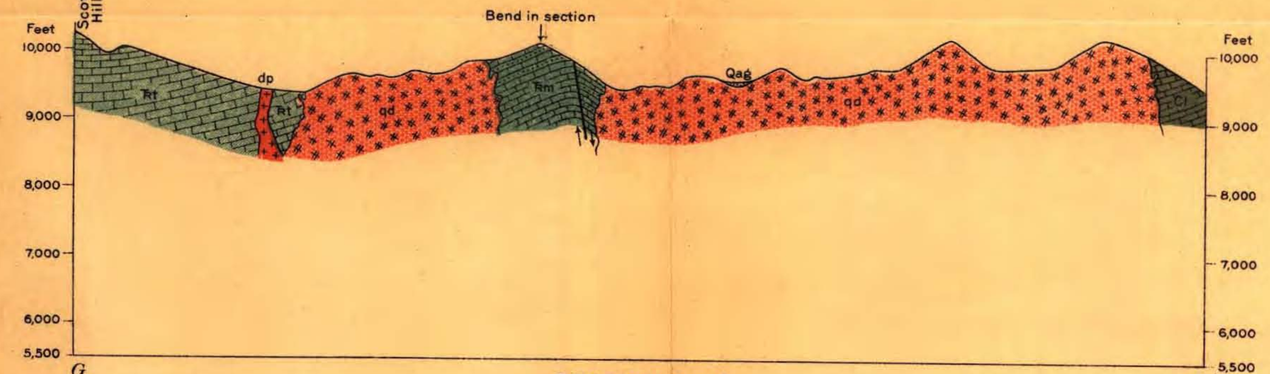
SECTION F-F'



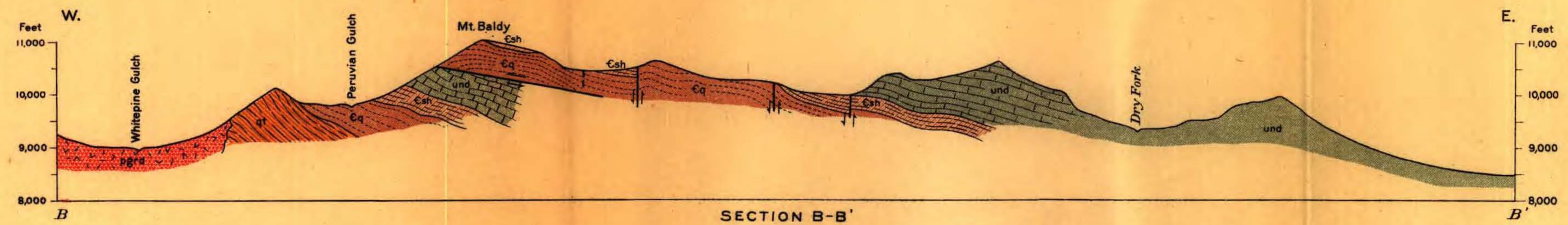
SECTION A-A'



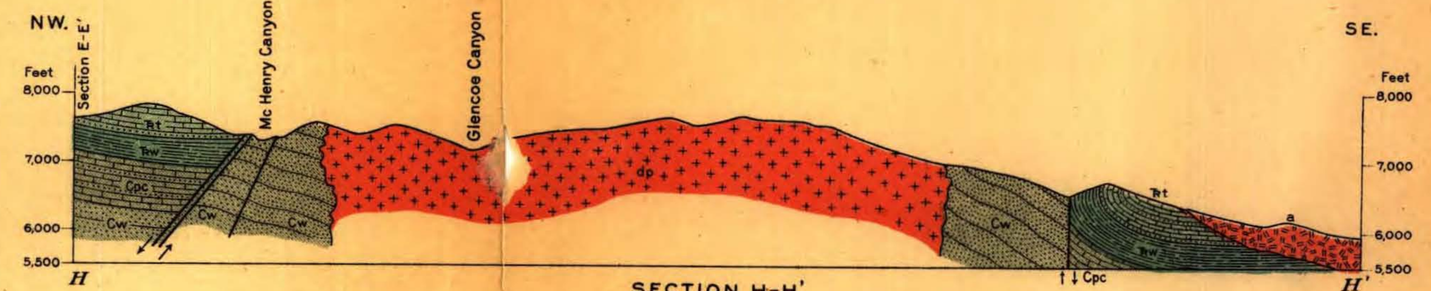
SECTION E-E'



SECTION G-G'



SECTION B-B'



SECTION H-H'

GEOLOGIC MAP OF THE COTTONWOOD AND PARK CITY DISTRICTS, UTAH

THE MAPPING WEST OF 111° 34' IS PRELIMINARY

Scale $\frac{1}{25000}$

1 Mile

1 Kilometer

Contour interval 50 feet.

Datum is mean sea level.

Readjustment of levels shows that elevations east of 111° 34' are 11 feet too high

1918